

ALIGNING INDIGENOUS KNOWLEDGE
WITH MONTANA'S MIDDLE SCHOOL
PHYSICAL SCIENCE STANDARDS

by

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DEDICATION

I dedicate this capstone to my parents, who chose to raise me within a Native American community even though we are not Native. As an outsider, I was given the rare gift of growing up surrounded by stories, traditions, and ways of knowing that were not originally my own. You made it clear that this was something to honor and respect.

You taught me that knowledge is powerful, and that wisdom does not come from just one culture. From you I learned there are multiple versions of history, all depending on the perspective of the recorder. You showed me that real learning requires listening—especially to voices that mainstream histories often overlook. You encouraged me to seek understanding wherever it can be found, and to approach every opportunity with gratitude rather than entitlement.

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ABSTRACT

Science instruction in Montana is required to include Indigenous perspectives through Indian Education for All (IEFA), yet few resources exist that embed Native knowledge in ways that align with the Montana middle school physical science standards. This leaves teachers without lessons to engage student with connections to their culture and community. The purpose of this project is to design and justify a set of physical science lessons that authentically integrate Indigenous knowledge while meeting Montana's middle school science standards.

This project uses an educational scholarship design approach to develop nine lesson plans aligned with Montana's middle school physical science standards related to forces, energy, matter, and waves. Lessons are constructed using the 5E instructional model and incorporate place-based phenomena, Indigenous perspectives, and Claim-Evidence-Reasoning assessments. Development of the content included analysis of standards, identification of meaningful connections to Native knowledge, particularly from Crow and Northern Cheyenne tribes, and review for cultural accuracy and alignment with IEFA principles.

This project has created rigorous, standards-based physical science lessons that authentically embed Indigenous knowledge without reducing it to supplemental content. The lessons encourage using Native perspectives to enhance understanding, increase student engagement, and support connections between scientific ideas and real-world experiences. The use of structured instructional frameworks allows for consistency, while place-based activities support relevance of tribal history, culture and knowledge.

Embedding Indigenous knowledge into physical science is both feasible and necessary in science education in Montana. This work helps bridge the gap between policy and classroom practice. Cultural, place-based science instruction can strengthen student learning, support identity, and promote an inclusive understanding of science as a discipline that values multiple ways of knowing.

CHAPTER ONE

INTRODUCTION AND BACKGROUND

The Need for Native American Science Resources

In Montana, we recognize the importance of integrating Native knowledge into our schools, as demonstrated by the Indian Education for All (IEFA) legislation (Montana Office of Public Instruction, n.d.). While this law requires the inclusion of American Indian heritage across all subject areas, science, especially physical science, still lacks resources that meet both IEFA goals and the state standards. Most existing materials focus on social studies or language arts, leaving science teachers to adapt or create lessons on their own. Many educators want to honor the spirit of IEFA but may not have the time, training, or knowledge to create physical science instruction that includes Native knowledge. Some teachers may be hesitant to include Native content without clear guidance, fearing that their lessons might feel inauthentic, overly simplistic, or lacking substance.

Incorporating Native knowledge into science education is especially meaningful in places like Hardin Middle School, located adjacent to the Crow Reservation. Of the school's 359 students, 81% identify as Native American—primarily from the Crow (Apsáalooke) and Northern Cheyenne (Tsétsêhéstâhese) Nations. Hardin Middle School students are resilient, creative, and demonstrate strong potential when engaged in meaningful, hands-on learning connected to their lives and communities. Current assessment data indicate that 40% of students score above the 50th percentile in English Language Arts, and 19% score above the 50th percentile in Math (T. Hardy, personal communication, 2024). These data underscore the

importance of instruction that is both academically rigorous and culturally relevant, helping students see the importance of their own experiences and background knowledge.

Hardin School District's administration includes a dedicated IEFA coordinator to ensure the law is being followed in each of the district's seven schools. Some of the ways the IEFA Coordinator incorporates American Indian culture in our schools include planning and carrying out events such as school-wide pow wows, tipi building, fashion shows highlighting Native designers, and guest speakers. While these activities are meaningful and contribute to cultural awareness, incorporating Native perspectives into the classroom and connecting it to specific content areas falls to individual teachers.

While searching for authentic and engaging activities to incorporate into my classroom, I found a valuable source of materials through the American Indian Science and Engineering Society (AISES), a national education organization that supports teachers working in communities with majority Native populations (Fostering Indigenous Innovation in Robotics Education, 2025). AISES offers numerous programs and provides professional development, including sending AISES representatives to Hardin in 2025 to deliver training with Climate Action Kits to our science teachers. Climate Action Kits use Micro:bits to explore environmental issues through coding and technology. A Micro:bit is a small, palm-sized computer with programmable LEDs, buttons, and sensors. In addition to providing the kits and training, AISES also shares lesson plans introducing students to specific Indigenous Nations, their languages, cultural values, and environmental challenges. The lessons combine traditional knowledge with coding and engineering skills, bridging the gap between historic heritage and modern-day technology.

Additionally, I discovered a grant-funded professional development opportunity through Utah State University titled Indian Education and Computing for All (Utah State University, 2020). This program provided lesson plans integrating technology with social studies instruction. The lessons used electric circuitry, conductive thread, Circuit Playground Express (CPX) controllers, and App Inventor to discuss treaties, explore food scarcity on reservations, and create an app for recipes using indigenous foods. These professional experiences have demonstrated to me that Indigenous knowledge can be authentically and meaningfully integrated into any content area in ways that are both relevant and contemporary.

Significance of the Project

The resources offered by this project gives science educators a model for integrating Indigenous knowledge into standards-based physical science curricula in culturally responsive and academically rigorous ways. While this project was designed with Hardin Middle School students in mind, its intended audience extends beyond my classroom. This work is for middle school science teachers across Montana who are required to implement IEFA but lack practical, standards-aligned physical science resources. It is especially relevant for educators teaching in districts near tribal communities, but it is equally applicable to teachers in predominantly non-Native districts who are also responsible for IEFA implementation.

This project contributes to the field of science education by addressing a gap between policy and practice. While IEFA legislation mandates the inclusion of Native culture across subject areas, few physical science resources demonstrate how to authentically integrate Indigenous knowledge into standards-based instruction. This capstone contributes a practical

model for embedding Indigenous knowledge into core physical science concepts such as forces, energy transfer, and thermal systems without reducing Native perspectives to historical artifacts.

I have built these resources with three replicable components: standards alignment, structured lesson design, and cultural integration. Each lesson is aligned with Montana's middle school physical science standards, allowing other educators to adopt or adapt the lessons without sacrificing required content. The lessons are built using the 5E framework, providing a familiar format that teachers can replicate. While the lessons are rooted in Crow and Northern Cheyenne perspectives, teachers in other regions can replace local examples with knowledge from tribal Nations in their own communities. Because the approach emphasizes structure, standards, and respectful integration, it offers a scalable model for educators seeking to include Indigenous knowledge in their classroom.

Purpose of Study

The purpose of this Educational Scholarship capstone is to design and justify a set of IEFA-aligned middle school physical science lessons that authentically integrate Indigenous knowledge while meeting Montana's state standards. This project explores ways Native knowledge can be embedded into physical science lesson plans, to increase student engagement and connect students to Native culture and thinking. By using traditional knowledge, these lesson plans aim to demonstrate the relevance of Indigenous knowledge to modern science education. This supports academic achievement, gives deeper respect for diversity and creates a more inclusive classroom.

This project aims to embed Native knowledge into nine standards-aligned physical science lessons in ways that explicitly highlight the relevance and importance of the knowledge.

The lessons highlight Native perspectives and culture, showing how they can enhance our current understanding of the concepts. They also highlight Native contributions to scientific understanding, emphasize place-based knowledge, and demonstrate how Native worldviews can enhance Western scientific perspectives. The ultimate goal was to create a science curriculum that is empowering for Native and non-native students.

CHAPTER TWO

CONCEPTUAL FRAMEWORK

Indigenous Knowledge as Legitimate Science

The conceptual foundation for embedding Indigenous knowledge into Montana's middle school physical science standards can be organized in three connected levels: (1) Indigenous knowledge as legitimate science, (2) historical suppression and educational policy, and (3) standards-based integration and curriculum design. Together, these levels tell a layered story. First, the literature establishes that Indigenous knowledge systems are rigorous, empirical, and deeply rooted in observation of the natural world. Second, it examines how colonization and assimilationist schooling systematically suppressed these systems. Third, it explores how contemporary legislation and standards create opportunities to restore Indigenous perspectives within science instruction. This multi-level structure moves from legitimacy, to suppression, to restoration and design, providing a comprehensive framework for authentic integration.

To establish the legitimacy of Indigenous knowledge systems, it is necessary to examine pre-colonial educational structures as scientific systems, consider the relationship between identity and representation in schooling, and explore our current education system for respectful integration. Together, these perspectives position Indigenous knowledge not as supplemental cultural content, but as a rigorous and enduring system of understanding the natural world.

Pre-Colonial Educational Systems as Scientific Systems

Long before Columbus arrived in North America in 1492 and long after first European contact, Native American communities sustained complex educational systems in which elders

and knowledge keepers instructed both adults and children. Before colonization, Native education was grounded in oral tradition, where knowledge was transmitted across generations through storytelling, observation, mentorship, ceremony, and direct participation in community life. The extended family played a central role in teaching practical survival skills, cultural values, ecological understanding, and tribal history. Education was inseparable from daily life and deeply intertwined with community values (Grinde, 2009).

Prior to widespread colonization in the fifteenth and sixteenth centuries, Indigenous people across North America were agriculturalists, land and seaside managers, hunters, fishers, engineers, and scientists (Grinde, 2009). Their knowledge systems were empirical and observational, grounded in sustained interaction with land, water, weather patterns, and seasonal cycles. Scientific understanding developed through repeated experimentation, close environmental observation, and collective refinement over generations. Indigenous science was not informal or incidental; it was systematic, adaptive, and place-based.

Identity, Representation, and Student Outcomes

Most students' negative stereotypes and misconceptions about Native Americans, along with limited exposure to history and culture from a Native perspective, have an adverse effect on for Native students' quality of life and educational experiences (Spang-Willis, 2013). These misunderstandings are not harmless gaps in knowledge; they shape how Native students are perceived, valued, and treated within schools and broader society. Research has linked cultural marginalization and identity suppression to increased rates of depression, substance abuse, and disengagement in Native communities (Spang-Willis, 2013). When curriculum ignores or distorts

Indigenous knowledge, it contributes to a broader pattern of invisibility that affects students' sense of belonging and self-worth.

Conversely, when Indigenous knowledge and beliefs are communicated accurately, respected, and learned, students from all cultural backgrounds develop greater understanding of themselves and one another. Cultural affirmation within curriculum supports stronger identity formation, engagement, and resilience. Representation within science classrooms signals to Native students that their communities are contributors to knowledge, not merely subjects of historical study (Spang-Willis, 2013).

Respectful Integration of Indigenous Knowledge into Science Curricula

While colonial systems marginalized Indigenous education (Grinde, 2009; Spang-Willis, 2013), scholars such as Kirkness and Barnhardt (1991) propose frameworks grounded in respect, relevance, reciprocity, and responsibility to guide meaningful inclusion of Indigenous ways of knowing. These principles emphasize relational accountability and authentic partnership rather than token representation. Integration requires more than adding cultural references; it demands structural shifts in how knowledge is framed and valued.

Together, the literature establishes that Indigenous knowledge systems are rigorous, place-based, and deeply empirical (Grinde, 2009). It demonstrates that Indigenous educational systems functioned as sophisticated scientific frameworks long before European contact, while also highlighting the critical connection between representation and student well-being (Spang-Willis, 2013). Frameworks of respect and reciprocity (Kirkness & Barnhardt, 1991) further reinforce that Indigenous knowledge must be treated as legitimate science rather than peripheral

enrichment. Recognizing this legitimacy requires examining how and why it was historically denied.

Historical Suppression and Educational Policy

Although Indigenous communities sustained complex scientific systems, colonization disrupted these systems and reshaped formal schooling in ways that marginalized Native education. Colonization institutionalized the suppression of Indigenous knowledge through education systems that functioned as mechanisms of replacement rather than inclusion. Understanding this history clarifies why intentional integration within middle school physical science is both academically necessary and ethically significant.

Colonization and Educational Erasure

Native American knowledge and beliefs were targeted and stifled by the U.S. government in the late 19th century to encourage Euro-American academics. Education was the transformative voice that would reshape Native Americans into "civilized" people in the minds of Euro-Americans, according to Grinde (2009). In 1879, Richard Henry Pratt, a Civil War and Indian War veteran, established the Carlisle Indian Industrial School in Pennsylvania, explicitly intending to replace Native understandings and culture with knowledge and skills valued in white society (Grinde, 2009). Native children were removed from their homes, forced to cut their hair and wear Euro-American clothes, prohibited from speaking their languages, and immersed in Euro-American curricula. Pratt's motto, "Kill the Indian...and save the man," reflected the explicit goal of cultural eradication.

Most Native American children who experienced boarding schools returned home with portions of their Native knowledge and culture diminished, and some developed prejudice against their own traditions (Spang-Willis, 2013). The boarding school system sought to “civilize” Native children by substituting Euro-American knowledge, religion, and language for their cultural understandings, often creating internalized shame and disconnection from community traditions. Generations of Native students experienced not only educational disruption but also erosion of cultural identity and traditional knowledge systems (Grinde, 2009; Spang-Willis, 2013).

Despite these efforts, Indigenous communities demonstrated extraordinary resilience. Many children preserved fragments of songs, stories, ceremonies, and ecological knowledge, carrying them back to their communities. Native knowledge systems endured not because colonization was benign, but because communities actively resisted erasure and protected their intellectual traditions. The continued presence of Indigenous science today reflects perseverance in the face of systematic suppression.

Replacing Indigenous Knowledge with Colonized Schooling

Education during the boarding school era functioned not merely as schooling but as a total replacement of indigenous knowledge, languages, and worldviews. Indigenous ways of knowing were framed as inferior or unscientific, while European academic traditions were institutionalized as the standard for legitimacy (Grinde, 2009). This hierarchy positioned Euro-American science as objective and universal while dismissing Indigenous science as mere myth or superstition. Suppression was institutional rather than incidental, embedding dominant norms into curriculum, assessment, and teacher preparation (Grinde, 2009; Spang-Willis, 2013).

Recognizing this history reframes contemporary integration not as enrichment, but as the validation and inclusion of diverse knowledge systems. If schooling once operated to erase Indigenous knowledge, then restoration within curriculum represents corrective action.

Legislative Response and Structural Restoration

In response to this history, policy has sought to restore Indigenous representation within public education. In 1999, the Montana State Legislature passed the Indian Education for All (IEFA) Act to fulfill the constitutional mandate recognizing the distinct and unique cultural heritage of American Indians (Montana Office of Public Instruction, n.d.). Then, in 2007, the Montana State Legislature passed Montana Code Annotated (MCA) 20-9-330 (Appendix A), appropriating funds to school districts to support American Indian students in their educational journey and work to close the statistical achievement gap. As part of the Tribal Student Achievement and Relations unit (TSAR), a key element of the American Indian Student Achievement Specialists' work is to engage tribes in consultation (Montana Office of Public Instruction, n.d.). American Indian Student Achievement Specialists are committed to helping all students by developing and implementing Indigenous supports. They feel that all Montanans can benefit from the Indigenous knowledge that endures today. To integrate tribal voice, exchange resources, and establish connections through consultation on issues impacting Native American students, the TSAR unit seeks to establish relationships and understandings within the Office of Public Instruction and Montana school districts. To further involve their youth population in education, tribal elders are brought into a supportive position through consultation.

The IEFA Act, House Bill 528, and House Bill 338 are all part of Montana's IEFA legislation. The purpose of the law is to teach Montanans about Native American culture and

history in the public school system. Its goals include ensuring that all Montanans have an awareness of Native American history, preserving Native culture, and acknowledging their cultural legacy. In addition to requiring school districts to submit expenditures to the Montana Office of Public Instruction (OPI), which supplies instructional materials, the Montana Legislature provides funding for IEFA. IEFA trainings are provided by Montana University System. MCA 20-9-329 was amended in 2023 to reduce future funding for school districts who fail to disclose IEFA spending (Montana Office of Public Instruction, n.d.).

These legislative efforts acknowledge that exclusion of Indigenous knowledge was systemic rather than accidental. However, policy alone cannot restore what systemic efforts to eliminate indigenous culture attempted to erase. Without intentional classroom implementation, legislative mandates risk becoming symbolic rather than transformative. Restoration depends on instructional design that authentically embeds Indigenous knowledge within disciplinary standards.

Standards-Based Integration and Curriculum Design

While policy signals commitment to restoration, meaningful change depends on classroom implementation. Embedding Indigenous knowledge within Montana's middle school physical science standards requires alignment with disciplinary core ideas, instructional practices, and assessment frameworks. When we examine tensions between multicultural education and standards-based systems we can identify curricular gaps and propose instructional strategies for authentic integration.

Multicultural Education vs. Standards-Based Systems

Educators must challenge assessment paradigms to achieve equity (Sernak, 2008). True inclusion requires reconsidering how comprehension is evaluated and recognizing multiple ways of knowing. Students crave representation of their cultural identities in classrooms (Kirkness & Barnhardt, 1991). Authentic integration therefore demands both curricular and assessment reform. Without attention to evaluation practices, integration risks being superficial rather than transformative.

Gaps in Science Curriculum Representation

Other states outside of Montana mandate Native American education. Though there is still work to be done, in a study by Broddus (2019) nearly 90% of states questioned reported that they are taking steps to enhance the caliber and accessibility of Native American curricula. Native American education was included in state standards in 82% of the states that responded to that poll ($N=28$), mainly in social studies. This is a good starting point, but other content areas need to be addressed. Native American experiences and contributions can be taught in multiple subject areas, such as art, literature and science. (Broaddus, 2019).

On Montana Office of Public Instruction (OPI) website, nine middle school science lessons are available. As can be seen in the list below, none of these lessons focus on physical science content (Montana Office of Public Instruction, n.d.):

- Cell Observation Skills - Grades 6-8
- Dating Deep Blood Kettles - Grades 6-8
- Human Impacts on the Environment - Fire on the Land - Grades 7-8
- Investigating the First Peoples, the Clovis Child Burial

- Montana Skies - Grades 4-8
- Blackfeet Astronomy
- Crow Astronomy
- Blackfeet and Crow Star Stories Lesson for Students
- Smallpox Epidemic of 1837 PowerPoint - Grades 6-12

These lessons focus primarily on life and earth science, and few have any physical science content. Of the 52 science standards that are required in middle school, 18 of them are physical science. There is a significant portion of the science content that is not represented in the available resources and lacks Indigenous representation.

Limiting Indigenous perspectives to history courses subtly reinforces the misconception that Native knowledge belongs only to the past. When physical science excludes Indigenous contributions, it perpetuates the idea that scientific knowledge is exclusively Western. Expanding Indigenous representation into physical science is therefore both an academic necessity and an equity imperative.

Alignment with Montana Middle School Physical Science Standards

The most recent scientific standards for Montana were approved in 2016 and are divided into six standard topics that are taught to students in grades K–12 (Appendix B). Process skills, physical and chemical sciences, biological sciences, earth sciences, scientific technical advancements, and scientific historical developments are the six topics covered by the standards. To give clarity and specificity across grade levels, Montana's standards additionally incorporate

Essential Learning Expectations (ELEs) for each grade level (Montana Office of Public Instruction, n.d.).

The Physical Science standards include understanding and investigating energy, matter, motion and forces, light, waves and atomic structure. The standards emphasize connecting science content across disciplines and encourage students to apply design practices and technology to solve problems. To help students learn by observing the natural world, phenomena-based learning and project-based learning are encouraged. Model curriculum guides by grade level are made available on the OPI website (Appendix C) (Montana Office of Public Instruction, n.d.).

OPI documentation states that science shall be taught to students through the integration of technology, science and engineering techniques, cross-cutting concepts, and content area ideas. Science content standards guarantee that all students, in all subject areas, are exposed to the history, modern representations, and contributions of American Indians, with a focus on Montana Indians (Montana Office of Public Instruction, n.d.). Students can learn that Native Americans use scientific knowledge and methods, and their knowledge is an authentic means of learning about the natural world.

Montana's science standards emphasize hands-on, phenomena-based learning and cross-curricular connections, which creates a way to authentically integrate Indigenous knowledge to physical science concepts, such as energy, matter, and forces. Incorporating this knowledge not only aligns with state standards but also enhances the curriculum by making science more relevant for students.

Instructional Design for Authentic Integration

Operationalizing this alignment requires deliberate instructional strategies. Aligning lessons to Montana’s middle school physical science standards, anchoring instruction in observable phenomena, utilizing the 5E instructional model, and incorporating Claim-Evidence-Reasoning (CER) assessments embed Indigenous knowledge as a rigorous component of physical science instruction.

When scholarship on equity (Sernak, 2008; Kirkness & Barnhardt, 1991), historical analysis (Grinde, 2009; Spang-Willis, 2013), and legislative mandates (Montana Office of Public Instruction, n.d.) are considered together, they reveal both a gap and an opportunity. Indigenous knowledge systems are empirically grounded scientific frameworks. Colonization institutionalized their suppression. Contemporary policy provides structural mechanisms for restoration. Meaningful implementation, however, requires educators to design classrooms that are academically rigorous and historically restorative.

Across these three levels—legitimacy, suppression, and restoration—the literature reveals a coherent narrative of intellectual marginalization and enduring resilience. Indigenous knowledge systems represent rigorous scientific traditions rooted in empirical observation and sustained environmental engagement (Grinde, 2009). Colonization sought to erase these systems through assimilationist schooling (Spang-Willis, 2013). Contemporary legislation such as IEFA establishes structural commitments to restoration (OPI, n.d.), yet the realization of that commitment depends on instructional practice. Embedding Indigenous knowledge within Montana’s middle school physical science standards is not merely curricular enrichment; it is an act of educational equity and epistemic justice. Through intentional alignment with phenomena-

based learning, the 5E model, and CER assessments, science classrooms can become spaces where academic rigor, cultural affirmation, and historical accountability coexist.

CHAPTER THREE

INSTRUCTIONAL STRATEGIES AND RESOURCES

Introduction to Strategies and Resources

The purpose of this project was to design nine lessons aligned to the Montana middle school physical science standards that authentically integrate Native knowledge. In these lessons, Native knowledge is embedded into science instruction to increase student engagement and demonstrate the relevance of Indigenous perspectives in science. The lessons highlight Native contributions, emphasize place-based learning, and show how Indigenous worldviews can complement scientific understanding. The goal is to create a more inclusive, respectful, and rigorous science curriculum for both Native and non-Native students.

This chapter includes instructional resources to support implementation of these lessons, including: 5E/7E lesson summaries, standards alignment table, list of phenomena engagement used in the lessons, place-based and Native knowledge connections presented, and Claims, Evidence, and Reasoning (CER) assessments. Together, these resources provide teachers with a clear, adaptable roadmap for integrating Native knowledge into middle school physical science instruction while maintaining rigor and alignment to state standards.

The instructional strategies used to create the middle school physical science lessons that integrate Native knowledge, Montana's science standards and Indian Education for All (IEFA) have been used before, but the combination of these strategies organize the lessons in a way to include multiple perspectives while maintaining the teaching of the concepts required by the state. The history, culture, and policy established in the conceptual framework make the

strategies used in developing lessons very important. The lessons have been created to change how we use Native knowledge in science and are supported by using 5E lesson planning, standards alignment, engagement through phenomena, and CER assessments. These strategies are intended to support inquiry-based learning, promote Native perspective, and create connections between scientific concepts, and students' background knowledge.

Instructional Strategies for Creating Place-Based 5E Lesson Plans

Perhaps the most important instructional strategy I used to create middle school physical science lessons was to construct them using the 5E lesson plan model and intentionally embed place-based learning and Native knowledge, fulfilling the IEFA requirements (Gerges, 2022). This integrated approach ensures that the lessons align with Montana Science Standards, support inquiry-based learning, and provide students with meaningful opportunities to connect science concepts to their communities, cultures, and personal experiences.

The 5E lesson model formats lessons to encourage inquiry and investigation. Each lesson is organized into five phases—Engage, Explore, Explain, Elaborate, and Evaluate—that guide students through a complete cycle of inquiry-based learning. The lesson introduction, or 'Engage' section, uses a phenomenon to initiate curiosity, engage the student, and connect the content to prior knowledge. In 'Explore', students conduct hands-on investigations to gather evidence. In the 'Explain' portion of the lesson, students develop models and construct explanations based on evidence from their investigations. This is supported by the teacher, but the teacher is not necessarily doing the explaining. 'Elaborate' is when the students apply knowledge to cultural examples. This may be where much of the indigenous knowledge is

introduced. To ‘Evaluate’, project-oriented assessments and CER assessments will demonstrate learning from the lesson.

To implement the 5E plans, teachers must play a supporting role. During the Engage phase, teachers introduce a relevant phenomenon and ask open-ended questions such as “What do you notice?” and “What do you wonder?” to encourage critical thinking without providing answers. In the Explore phase, teachers organize hands-on investigations, provide materials, and observe, question, and guide student inquiry using prompts like “What patterns are you seeing?” or “What evidence do you have?” During Explain, teachers support students’ understanding by leading discussion, asking for evidence-based explanations, and introducing vocabulary after students have shared their ideas. In the Elaborate phase, teachers connect concepts to Indigenous knowledge and place-based examples by incorporating stories, local practices, or community knowledge, while leading students to make connections between multiple ways of knowing. Finally, in the Evaluate phase, teachers assess student understanding through CER responses, models, or performance tasks, providing feedback about students’ reasoning.

5E lesson planning was originally developed by the Biological Sciences Curriculum Study (BSCS) to be used with inquiry-based science instruction (Bybee et al., 2006). It is designed to support students with phenomena, investigation, explanation, application of knowledge, and assessment. 5E plans ensure student engagement by requiring active participation in the learning process (Bybee, 2014).

The 5E lesson plan easily transforms into the 7E lesson plan if you add a section for ‘Environment’ and another for ‘Elder’ (CRIS Project Team, 2019). In Native American culture, an elder is a respected community member, not strictly defined by age, who acts as a guardian of

knowledge, traditions, and spirituality. They are revered for their wisdom, serving as leaders, mentors, and storytellers who transmit cultural heritage to younger generations (We R Native, n.d.). Most of the lessons created lent themselves to this framework. Ideas for elder viewpoints and commentary were included in the lessons, but in some cases, finding relevant elder resources for specific concepts was difficult.

To adapt this structure to a 7E lesson plan, teachers need to find ways to deepen cultural relevance. The Environment section provides opportunities to add activities that allow students to interact directly with their local surroundings, such as outdoor investigations, community observations, or analysis of local phenomena. In the Elder section, teachers could invite community members, use recorded interviews, or incorporate documented stories and teachings. When direct access to an Elder is not possible, teachers can still honor this component by using tribally specific, vetted resources. The 5Es and 7Es are not necessarily linear but the framework moves students from curiosity to deep understanding, emphasizing that learning occurs when students are engaged in inquiry. Teachers direct the learning process, allowing students to build their own understanding, investigate problems, and construct knowledge rather than just receiving information (American Psychological Association PsycNet, n.d.).

The purpose of the 5E and adapted 7E lesson structure is to provide a research-based, inquiry-driven framework that supports students in understanding through investigation and reflection. This positions Indigenous knowledge as a legitimate, rigorous, and observational form of science, rather than as supplemental content. By emphasizing investigation, the 5E model aligns with pre-European educational systems described by Grinde (2009), where learning occurred through participation, observation, and community interaction.

Teachers can adapt the 5E lessons based on their classroom context, time constraints, and student needs. For example, a teacher might extend the Explore phase over multiple days for deeper investigation, integrate the Elaborate phase throughout the lesson rather than as a single step, or revisit the Engage phenomenon at the end of the lesson to reinforce learning. Teachers may also adjust the level of scaffolding and differentiation depending on student experience with inquiry, providing more structured guidance for beginners and gradually releasing responsibility as students become more independent. Importantly, teachers should adapt place-based and Indigenous components to reflect the specific tribal communities represented in their classrooms, ensuring that integration is meaningful, accurate, and respectful rather than generalized.

Teachers can use these 7E lessons to embed Indigenous perspectives within each phase of instruction, ensuring that cultural knowledge is integrated throughout the lesson rather than isolated in a single activity. Additionally, the inclusion of “Elder” and “Environment” as extensions of the model reflects the principles of respect, relevance, reciprocity, and responsibility (Kirkness & Barnhardt, 1991). By creating space for multiple perspectives within the lesson plan, this approach responds to the historical suppression of Indigenous knowledge.

The choice between using a 5E or 7E lesson format should depend on a teacher’s instructional goals and access to community resources. The 5E model is effective for maintaining focus on inquiry and conceptual understanding. The 7E model, however, is particularly valuable when teachers are able to incorporate direct connections to community, culture, and place through the addition of “Environment” and “Elder.” Teachers might use the 7E structure when opportunities exist to engage with local landscapes, tribal knowledge, or community members, making learning more relational. This decision directly supports the goals of IEFA outlined in

Chapter 1, which emphasize the integration of Native perspectives and knowledge in all content areas. The lessons included in this project include Elder and Environment activities, but their exclusion would not adversely affect learning. The following section demonstrates how standards alignment ensures that culturally responsive approaches remain rigorous, intentional, and fully integrated within Montana's science requirements.

Standards Alignment

Lesson development began by carefully analyzing the Montana middle school physical science standards. Standards were grouped into conceptually related clusters to support lessons that are rigorously interconnected. The lessons have been built to follow the standards while highlighting authentic and relevant Indigenous knowledge. These lessons are intended to fit seamlessly into my current unit design, including supporting student learning demonstrated with performance-based assessments. Each lesson is intentionally aligned with both content and skills, including modeling, data analysis, and scientific explanation.

The purpose of standards alignment is to ensure that the integration of Indigenous knowledge still meets Montana's middle school physical science requirements. By aligning lessons to specific standards, teachers can show that Native knowledge is as important as Western scientific content. Educators can use this alignment to design lessons that meet content expectations and IEFA requirements. This will ensure that the integration strengthens rather than competes with the content. This approach to equity in education (Sernak, 2008), addresses the gaps in science curriculum representation (Broadus, 2019), particularly in physical science, by intentionally embedding Indigenous perspectives. Aligning lessons to standards ensures that integration is sustainable, defensible, and transferable across classrooms, supporting teacher

implementation. Table 1 shows how each lesson created in this project aligns with the Montana middle school science standards (Appendix D).

Table 1. Lesson Alignment with Montana Middle School Physical Science Standards.

Standard(s)	Lesson Summary	Modification Suggestions
Lesson 1: Everything Is Connected – Modeling Matter Through Relationships		
MS-PS1-1: develop and critique models that describe the atomic composition of simple molecules and extended structures.	Elder: Discover Fred Begay (Clever Fox), physicist who showed how native knowledge supported him as a scientist.	Clever Fox is Navajo but is inspirational to all cultures
	Engage: Students compare the patterns they see in beadwork, elk tooth dresses, and snowflake images to patterns in the periodic chart. These patterns will help students recognize how complex objects are made from smaller, connected parts.	Consider patterns important in the specific culture or community: leatherwork, beadwork, rugs, fabrics, carvings, etc.
	Explore: Students build models of atoms using beads to represent subatomic particles and their connections.	Materials other than beads could be used to create an atom model.
	Environment: Students compare their models to patterns found in nature, such as crystals or plant structures.	Choose natural items found in the specific area.
	Explain: Students describe their models and describe the patterns they see. Students will discover how everything can be divided into the smallest parts of atoms and molecules which shows how everything is linked together, and how we are connected to the natural world on an atomic level.	This activity is relevant in all communities and cultures.
	Elaborate: Students expand their models to show how their atoms connect to form ionic and covalent bonds.	This activity is relevant in all communities and cultures.
	Evaluate: Students use the Claims, Evidence, Reasoning (CER) format to answer the following guiding question: <i>“How do the patterns we see in the periodic table determine the properties of matter?”</i>	This activity is relevant in all communities and cultures.

Lesson 2: Chemistry in Natural Dyes and Pictographs		
MS-PS1-2: analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.	Engage: Students observe a color-changing pH indicator and pictograph images to question why materials change color and whether new substances are formed.	Try to find pictograph images from locations near the specific community.
	Elder: An Elder shares how natural materials were traditionally tested and selected for dyes and paints.	Ask an Elder from your community to discuss their traditional dyes and paints.
	Explore: Students rotate through lab stations to test color changes, observe gas production, combine materials to form a precipitate, and measure temperature changes during chemical reactions.	This activity is relevant in all communities and cultures.
	Environment: Students travel to Pictograph Cave to observe the cave drawings that have been there for thousands of years.	Visit a location that has pictograph paintings near the specific community.
MS-PS1-5: develop, use, and critique a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved.	Explain: Students create paints from local minerals, plants, charcoal and clays.	This activity is relevant in all communities and cultures.
	Elaborate: Students create pictographs using their paints and test the pigments over time in the sun.	This activity is relevant in all communities and cultures.
	Evaluate: Students use the Claims, Evidence, Reasoning (CER) format to answer the following guiding question: <i>“How do we know that a chemical reaction has occurred in pictographs?”</i>	This activity is relevant in all communities and cultures.

Lesson 3: Natural Resources, Synthetic Materials		
MS-PS1-3: gather information to describe that synthetic materials come from natural resources and impact society.	Engage: Students examine everyday objects and discuss whether they are natural or synthetic.	Choose natural materials traditionally used in the specific community.
	Elder: An Elder describes the changes through the years of materials used to create regalia.	Ask an Elder to explain how a materials used to make specific item in their culture has changed with the use of synthetic materials.
	Explore: Students rotate through stations to sort materials and test natural materials to compare properties.	Choose natural materials traditionally used in the specific community.
	Explain: Students learn that synthetic materials are made from natural resources and analyze differences in properties, uses, and impacts.	This activity is relevant in all communities and cultures.
	Elaborate: Students design a material that meets human needs while considering environmental impacts.	This activity is relevant in all communities and cultures.
	Evaluate: Students use the Claims, Evidence, Reasoning (CER) format to answer the following guiding question: <i>“How do synthetic materials affect the environment?”</i>	This activity is relevant in all communities and cultures.

Lesson 4: Heat, Shelter, and Balance – Understanding Thermal Energy		
MS-PS1-4: develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.	Engage: Students compare a modern house, a tipi, and a sweat lodge to question how different structures control heat.	Sweat lodges are still used by the Crow Tribe today. Tipis were the predominant shelter for the Crow. If sweat lodges or tipis are not used in the specific community, use examples of traditional shelters.
	Elder: An Elder shares knowledge about tipis and how they respond to outdoor temperature.	Have an Elder discuss how their traditional shelters were heated.
MS-PS1-6: undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes.	Environment: Students discuss animal homes to consider how heat is managed in their environment.	If the animals selected for this activity are not indigenous to the area, find articles about animals that are.
	Explore: Students investigate the difference in heat retention between a tipi and a home.	If tipis are not used in the specific community, build models of traditional shelters.
	Explain: Students learn how thermal energy affects particle motion.	This activity is relevant in all communities and cultures.
MS-PS3-3: apply scientific principles to design, construct, and test a device that minimizes or maximizes thermal energy transfer.	Elaborate: Students design and test a device based on Native technologies that controls heat, using data to improve their design.	Describe local tribal insulation technologies for students to replicate.
	Evaluate: Students use the Claims, Evidence, Reasoning (CER) format to answer the following guiding question: <i>“How does thermal energy move, and how can a design reduce heat transfer?”</i>	This activity is relevant in all communities and cultures.

Lesson 5: For Every Action – Reaction		
MS-PS2-1: apply Newton's Third Law of Motion to design a solution to a problem involving the motion of two colliding objects.	Engage: Students observe a canoe as it is propelled through the Big Horn.	Find a video of a traditional water transport vehicle for the specific area.
	Explore: Students investigate action-reaction forces through collisions, push-off, and canoe activities while collecting data on motion. Students use a canoe in a pond or the school pool to investigate action-reaction forces.	Use a traditional water transport vehicle for the specific area.
	Environment: Students connect their findings to movement in natural settings like animals running, flying, or swimming.	If the animals in the videos are not indigenous to the specific area, find videos of animals that are.
	Explain: Students learn that forces always come in equal and opposite pairs acting on different objects and apply this to their observations while playing Doubleball.	Doubleball is a game of the Plains Indians. Consider other games that are from the specific area.
	Elaborate: Students design and test a system that controls motion during a collision using their understanding of action–reaction forces.	Show students examples of transport technologies from the specific area.
	Evaluate: Students use the Claims, Evidence, Reasoning (CER) format to answer the following guiding question: <i>“How does Newton's Third Law explain why both objects move during an interaction?”</i>	This activity is relevant in all communities and cultures.
	Elder: An Elder reflects on how both scientific and Indigenous perspectives explain motion through relationships.	This activity is relevant in all communities and cultures.

Lesson 6: Forces and Motion – Learning from Tipis and Travois		
MS-PS2-2: plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.	Engage: Students observe a tipi in wind and a travois carrying weight to question how forces affect stability and motion.	Share with students that if tipis are not the traditional shelter of the specific area, this activity will not reflect the local community. If a travois is not the way cargo was transported, consider modeling a traditional vehicle of the specific area.
	Explore: Students build tipi models, pull weighted travois systems, and test motion on ramps to collect data on force, mass, and energy.	Share with students that if tipis are not the traditional shelter of the specific area, this activity will not reflect the local community.
MS-PS3-1: construct and interpret graphic displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object.	Environment: Students improve their travois to optimize stability, efficiency, or energy transfer.	If a travois is not the way cargo was transported, consider modeling a traditional vehicle of the specific area.
	Explain: Students learn that motion depends on net force and mass, and that kinetic energy depends on mass and speed.	This activity is relevant in all communities and cultures.
	Elaborate: Students design and improve a tipi to optimize stability.	Share with students that if tipis are not the traditional shelter of the specific area, this activity will not reflect the local community.
	Evaluate: Students use the Claims, Evidence, Reasoning (CER) format to answer the following guiding question: <i>“How do force and mass affect an object's motion and kinetic energy?”</i>	This activity is relevant in all communities and cultures.
	Elder: An Elder demonstrates how tipis were designed, building a tipi on the practice field.	If tipis are not the traditional shelter of the specific area, ask Elder to discuss their traditional shelter.

Lesson 7: Forces We Cannot See		
MS-PS2-3: ask questions about data to determine the factors affecting electric and magnetic force strengths.	Engage: Students observe magnets, static electricity, gravity, and drum vibrations to ask how objects can move or affect each other without touching.	Not all tribes use pow wow drums. If the specific area does not have this tradition, inquire as to what other type of drum you could use.
	Elder: An Elder discusses interconnected relationships between Earth, sky, water, and living beings.	This activity is relevant in all communities and cultures.
MS-PS2-4: construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the mass of interacting objects.	Explore: Students rotate through stations (magnetism, static electricity, gravity models) to investigate how distance, mass, and materials affect non-contact forces.	Research the significance of directions in your specific area. Use hides of animals indigenous to the specific area. Research how local tribes use irrigation.
	Environment: Students discover how animals use magnetoreception to navigate.	This activity is relevant in all communities and cultures.
MS-PS2-5: design and conduct an investigation to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact.	Explain: Students share data and learn that non-contact forces act through fields, and that force strength depends on distance, mass, and object properties.	This activity is relevant in all communities and cultures,
	Elaborate: Students design a magnetic deadfall trap showing non-contact forces and explain it using both scientific concepts and ideas of balance and connection.	If the local area Indigenous people do not use deadfall traps, consider modifying this challenge to model a local traditional trap.
	Evaluate: Students use the Claims, Evidence, Reasoning (CER) format to answer the following guiding question: <i>“How can an object change the motion of another object without ever physically touching it?”</i>	This activity is relevant in all communities and cultures.

Lesson 8: Energy in Relationships – Potential, Motion, and Transfer		
MS-PS3-2: develop and critique models to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system.	Engage: Students observe a stretched rubber band and falling objects to question where energy is stored before motion occurs.	Note: Although widespread, not all tribes used bows and arrows.
	Elder: An Elder shares how tools like bows demonstrate stored and transferred energy.	This activity is relevant in all communities and cultures.
	Explore: Students investigate how a bow and arrow transfer potential energy, thermal energy, and kinetic energy through hands-on stations while collecting data on energy changes.	Note: some tribes restrict female use of weapons. Research local traditions.
MS-PS3-4: plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample.	Explain: Students learn that energy is stored based on position and arrangement and transferred through motion and interactions between objects by comparing traditional weapons.	The weapons compared in this activity are used by the Crow tribe. Research local traditional weapons.
	Elaborate: Students compare clean energy to fossil fuels using Hopi perspectives. Students then use technology to build a light sensor with solar panels.	If you do not have access to the Climate Action Kits. The content in the AISES FIIRE lesson is still relevant.
	Environment: Students list local examples of potential energy and explain how they transfer to kinetic energy.	This activity is relevant in all communities and cultures.
MS-PS3-5: construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.	Evaluate: Students use the Claims, Evidence, Reasoning (CER) format to answer the following guiding question: <i>“How does changing the properties of a bow and arrow change how potential energy transforms to kinetic energy?”</i>	This activity is relevant in all communities and cultures.

Lesson 9: Observing Waves, Energy, and Light Through a Lens of Culture and Science		
MS-PS4-1: use mathematical representations to describe a simple model for waves that includes how the amplitude and wavelength of a wave is related to the energy in a wave.	Engage: Students observe and listen to a powwow drum and light demonstrations to question how waves carry energy and interact with materials.	Not all tribes use pow wow drums. If the specific area does not have this tradition, inquire as to what other type of drum you could use.
	Elder: An Elder shares the cultural significance of drum sound and how it connects people across distance.	Research traditional communication methods of the local area to use in this activity.
MS-PS4-2: develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.	Explore: Students investigate sound waves using a drum model and explore light behavior through hands-on testing with different materials and art design.	This activity is relevant in all communities and cultures that use any type of drums.
	Explain: Students learn that amplitude relates to energy and that waves can be reflected, absorbed, or transmitted depending on materials.	This activity is relevant in all communities and cultures that use any type of drums.
	Elaborate: Students create a design using cyanotype paper after viewing the buffalo hide designed with this process by a Rocky Boy artist.	This activity is relevant in all communities and cultures.
	Environment: Students investigate why snow reflects more sunlight than soil.	This activity is relevant in all communities and cultures.
	Evaluate: Students use the Claims, Evidence, Reasoning (CER) format to answer the following guiding question: <i>“How does amplitude affect the energy carried by a wave, and how do different materials affect the movement of light waves?”</i>	This activity is relevant in all communities and cultures.

Table 1 serves as a planning tool for educators seeking to integrate Native knowledge into middle school physical science instruction while maintaining alignment with Montana standards. By organizing each lesson around the 7E lesson format and clearly identifying where Indigenous knowledge and the standards intersect, the table provides teachers with a clear, usable model for lesson design. Educators can use this resource to guide their own planning by adapting the structure, activities, and cultural connections to fit their specific classroom context and local tribal communities. Suggestions for how each lesson could be thoughtfully modified are included. Table 1 functions not only as a summary of this project, but also as a resource that supports teachers in meeting the goals of IEFA.

Phenomena-Driven Engagement

Each lesson begins with a phenomenon—an engaging, real-world event that captures students’ curiosity and encourages them to ask questions and investigate further (Anderson, n.d.). Research on phenomena-based instruction suggests that anchoring learning in observable events promotes deeper understanding when students are investigators who build explanations from evidence rather than receiving information from the instructor. Phenomena anchor student learning and provide authentic reasons for investigation. For example, the energy transfer lesson might begin with an investigation of traditional Native dwellings, such as tipis, which were designed to efficiently regulate heat through shape, materials, and airflow. Students will compare this to modern homes in their community by collecting temperature data inside and outside different structures. This allows them to explore conduction, convection, and radiation in real-world contexts while recognizing Indigenous engineering knowledge. Using place-based phenomena helps students see science as relevant and worth investigating.

The purpose of using phenomena-driven engagement is to provide observable, real-world events that naturally invite questioning and investigation. This strategy reinforces the idea that Indigenous knowledge systems are grounded in empirical observation of the natural world. By beginning lessons with meaningful phenomena, especially those connected in a local context, students experience science in a way that mirrors how knowledge has traditionally been developed, through observation and interaction with the environment. Teachers can use this approach to increase student engagement and create authentic lessons for scientific concepts, particularly for students who may not see themselves represented in traditional science instruction. This strategy is reinforced by research on inquiry-based and phenomena-based learning (Anderson, n.d.), which shows that students develop deeper understanding when learning is driven by curiosity and investigation. Additionally, using place-based phenomena supports the principles of relevance and representation (Kirkness & Barnhardt, 1991; Spang-Willis, 2013), helping students connect scientific ideas to their own experiences and communities. In this way, phenomena serve as both a scientific and cultural bridge, linking Western scientific practices with Indigenous ways of knowing. Table 2 lists the phenomena used for each lesson (Appendix E).

Table 2. Phenomena Used for Each Lesson.

Lesson Number	Topic	Phenomena
1	Everything Is Connected – Modeling Matter Through Relationships	Objects like beadwork, elk tooth dresses, and snowflakes are made of repeating patterns built from smaller parts. Similarly, all matter is made of atoms that combine in specific ways to form molecules and larger structures.

2	Chemistry in Natural Dyes and Pictographs	Natural dyes, like red cabbage juice, change color when mixed with different substances, and reactions like vinegar and baking soda produce bubbles. These changes suggest that new substances may form.
3	Natural Resources, Synthetic Materials	Everyday objects like plastic bottles, clothing, and rubber items look very different, but all come from natural resources that have been processed in different ways. This raises the question of how materials are made and how those choices affect people and the environment.
4	Heat, Shelter, and Balance – Understanding Thermal Energy	Very different structures, like a modern insulated house and a tipi, can both keep people warm by controlling how heat moves. This shows that different designs can manage thermal energy using similar concepts.
5	For Every Action – Reaction	When two objects interact, like a canoe paddle in water, both objects move, even if only one seems to cause the motion. This shows that forces always occur in pairs, acting in opposite directions.
6	Forces and Motion – Learning from Tipis and Travois	A tipi remains stable in strong wind while a travois becomes harder to pull as more weight is added. These situations show how forces, mass, and motion interact in real-world systems.
7	Forces We Cannot See	Relationships are not always visible, but non-contact forces can move objects without touching, such as magnets pulling paper clips, balloons sticking to walls, and the Moon affecting tides.
8	Energy in Relationships – Potential, Motion, and Transfer	When a stretched rubber band is released or an object is dropped, stored energy is converted into motion. This shows that energy can be stored in systems based on position and then transferred when the position changes.

9	Observing Waves, Energy, and Light Through a Lens of Culture and Science	The sound of a powwow drum can be both heard and felt, and light changes when it interacts with different materials. These phenomena show that waves carry energy and behave differently depending on their amplitude and the materials they encounter.
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Teachers can intentionally select and adapt phenomena using events that are observable, relevant to students' lives, and aligned with the scientific concepts being taught. Effective phenomena are those that naturally invite questioning and can be investigated through available classroom resources. When possible, teachers should choose place-based phenomena connected to the local environment, community, or Native knowledge of the local tribes. Teachers could also adapt existing phenomena by modifying materials, incorporating local examples, or reframing questions to better reflect students' experiences and culture. By thoughtfully choosing and adapting phenomena in this way, teachers can create inquiry that is scientifically rigorous and includes Native perspectives.

Embedding Place-Based and Native Knowledge

The essential purpose of this project is the integration of place-based learning and Native perspectives. Research suggests that place-based education can increase student engagement and support the development of STEM identity by connecting learning to students' local environment, community, and lived experiences. By engaging in authentic, locally relevant investigations, students develop stronger problem-solving skills, a greater sense of agency, and increased confidence in their ability to contribute to their communities, making science learning more meaningful and relevant, particularly in rural settings (Mercier et al., 2025).

Each lesson will include connections to students' communities, environments, and cultural knowledge. The purpose of embedding place-based learning and Native knowledge is to center students' learning within their local environment while validating Indigenous perspectives as essential to understanding scientific concepts. This strategy affirms Indigenous knowledge as legitimate science and addresses its historical exclusion from formal education. By incorporating local environments, cultural practices, and Native perspectives, teachers can create lessons that are both meaningful and academically rigorous. Educators might use this approach by integrating local tribal knowledge, environmental observations, and culturally relevant examples into their instruction, ensuring that learning is connected to students' lived experiences. This strategy is grounded in research emphasizing the importance of identity in student outcomes (Spang-Willis, 2013), as well as frameworks of respect, relevance, reciprocity, and responsibility (Kirkness & Barnhardt, 1991). It also responds to the historical suppression of Native knowledge by intentionally restoring it within the curriculum. The choice to prioritize place-based learning reflects the understanding that knowledge is built through relationships and specific experiences. This approach matches both Indigenous views and modern teaching methods that honor students' backgrounds. Table 3 (Appendix F) gives the place-based activities and cultural knowledge used in each lesson.

Table 3. Place-Based Learning Used for Each Lesson.

Lesson Number	Topic	Place-Based Learning
1	Everything Is Connected – Modeling Matter Through Relationships	Patterns in beadwork, weaving, and nature reflect relationships that create meaning and function. These same ideas of pattern and connection help explain how atoms form matter in the natural world.

2	Chemistry in Natural Dyes and Pictographs	Native peoples use plants, minerals, and charcoal to create dyes and pictographs, observing how materials change under different conditions.
3	Natural Resources, Synthetic Materials	Native communities use locally available materials like hides, plants, and wood. Comparing these practices to modern synthetic materials helps students understand how these materials impact local environments.
4	Heat, Shelter, and Balance – Understanding Thermal Energy	Native communities designed shelters like tipis based on climate, airflow, and available materials to manage heat effectively. These designs reflect deep knowledge of how thermal energy moves in real environmental conditions.
5	For Every Action – Reaction	Movement through water and land depend on pushing against something to create motion. Native technologies like canoes reflect an understanding of these force relationships through observation and experience.
6	Forces and Motion – Learning from Tipis and Travois	Tipis and travois were designed using deep knowledge of wind, land, and movement to ensure safety, efficiency, and mobility.
7	Forces We Cannot See	Native people have observed how wind, water, land, and sky interact across distance. These observations reflect an understanding that relationships and forces shape movement and balance in the natural world.
8	Energy in Relationships – Potential, Motion, and Transfer	Energy relationships are observed in tools like bows, in gravity affecting movement across land, and in heating practices using stones and fire. These examples reflect how energy moves from place to place.

9	Observing Waves, Energy, and Light Through a Lens of Culture and Science	Sound (like drumming) represents connection and can travel across distance, while light and color are used in art and storytelling. These practices reflect an understanding of how waves move energy and interact with the environment.
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Teachers need to make intentional decisions when selecting place-based activities by considering their local environment, available resources, and the culture of their students. For example, a teacher in southeastern Montana might choose to connect a lesson on thermal energy to tipis or local housing structures, while another teacher might instead focus on how barns, trailers, or modern homes in their community retain heat. When teaching about forces, a teacher could decide to use a nearby river, playground equipment, or even winter conditions like pushing on ice to explore motion and friction, depending on what is most accessible to students. In selecting cultural connections, teachers might collaborate with local tribal members, use tribally specific resources, or adapt examples to reflect the tribes represented in their classroom rather than using general Indigenous content. Teachers also make decisions about how students will engage with place, such as choosing between outdoor investigations, community observations, or classroom simulations when access is limited. These decisions require balancing authenticity, respect, and feasibility while maintaining alignment to scientific concepts. By thoughtfully making these choices, teachers ensure that place-based learning is not only relevant and engaging, but also culturally meaningful and academically rigorous.

Claim, Evidence, Reasoning (CER) as an Assessment Framework

To strengthen students' ability to think critically and communicate effectively, Claims, Evidence, Reasoning (CER) responses were used to assess student understanding (McNeill & Krajcik, 2012). In this type of assessment, students make a 'Claim' or a conclusion based on data they have gathered from an investigation. The students then support their claim with 'Evidence' by describing their observations, data, or models. The student then writes their 'Reasoning', connecting the evidence to the claim (Appendix G). For each lesson, a claim is given to the students, then the students respond with their evidence to prove the claim and their reasoning. This scaffolding will help students that are unfamiliar with CER assessments (Appendix H).

The purpose of using the CER framework is to support students in constructing scientific explanations that are grounded in data and logical reasoning. This addresses the need for equitable assessment practices, especially when traditional evaluation methods often favor Western ways of knowing (Sernak, 2008). By using CER, teachers can create opportunities for students to demonstrate understanding through multiple forms of evidence, including observations, models, and cultural examples. Educators can implement CER as both a formative or summative assessment tool, guiding students to connect their experiences and investigations to scientific concepts. This approach reinforced by research on science literacy and argumentation (McNeill & Krajcik, 2012), which shows that students develop deeper understanding when they are required to justify their thinking. Additionally, CER aligns with Indigenous knowledge systems by valuing evidence derived from observation and experience, reinforcing the validity of multiple ways of knowing. The decision to scaffold CER claims within the lessons is an intentional effort to support all learners while maintaining high expectations for

scientific reasoning, ultimately contributing to a more inclusive and academically rigorous classroom environment. Table 4 list the claims for each of the nine lessons.

Table 4. Claims, Evidence, Reasoning Assessment Used for Each Lesson.

Lesson Number	Topic	Claims, Evidence, Reasoning Assessment (Claim given to students)
1	Everything Is Connected – Modeling Matter Through Relationships	Matter is made of atoms that combine in specific patterns using chemical bonds. The way atoms are arranged determines the properties of the material.
2	Chemistry in Natural Dyes and Pictographs	We know chemical reactions have occurred when substances change color, change odor, form a precipitate, form bubbles, change temperature, or give off light.
3	Natural Resources, Synthetic Materials	Synthetic materials affect the environment because they are made from natural resources. Synthetic materials provide useful products for society, but they can also contribute to pollution and waste in the environment.
4	Heat, Shelter, and Balance – Understanding Thermal Energy	Thermal energy moves through conduction, convection, and radiation, and insulation can reduce heat transfer.
5	For Every Action – Reaction	For every action force, there is an equal and opposite reaction force acting on a different object.
6	Forces and Motion – Learning from Tipis and Travois	The motion of an object depends on the amount of force acting on it and its mass. Kinetic energy increases as an object's mass or speed increases.
7	Forces We Cannot See	Non-contact forces move objects across a distance because the source object creates an invisible field that stores energy and exerts a push or pull on any interacting object that enters its boundaries.

8	Energy in Relationships – Potential, Motion, and Transfer	Modifying the bow's properties like type of wood or how far you pull the string causes varying amounts of potential energy to converted into kinetic energy.
9	Observing Waves, Energy, and Light Through a Lens of Culture and Science	Greater amplitude produces waves with more energy, and materials interact with light by reflecting, absorbing, or transmitting the wave depending on their properties.

The CER graphic organizer created to use with the lessons provides a structured tool for helping students construct scientific explanations based on their investigations. In this organizer, students could begin by identifying a scientific question, then develop a claim that directly answers that question or use a claim given to them by the instructor. They support their claim with evidence, drawn from data, observations, or investigations, and finally explain their thinking through reasoning, which connects the evidence to the claim using scientific principles. The inclusion of space for photos or sketches allows students to represent their thinking visually, supporting multiple ways of demonstrating understanding. In practice, teachers can use this organizer as both a formative and summative assessment by guiding students through each component, modeling strong responses, and gradually releasing responsibility as students gain confidence. This scaffolded approach helps students move beyond simply stating answers to explaining why those answers are valid, reinforcing critical thinking, scientific reasoning, and the integration of knowledge.

Content Development Process

To ensure that Native knowledge is integrated authentically and respectfully, this project followed a deliberate process for the content development of the nine lessons aligning

Indigenous knowledge with Montana's middle school physical science standards (Appendix I). Rather than treating Native knowledge as an add-on, each lesson was intentionally created with Native perspectives honoring tribal knowledge embedded in ways that align with the science concepts being taught. Lesson development began with identifying physical science standards and exploring where Native knowledge naturally connects to those concepts. Place-based content was included to ensure students' background knowledge was used as an engagement strategy. Whenever possible, Crow and Cheyenne tribal knowledge was used, but the lessons could be used anywhere in Montana and still be relevant. The lessons have been reviewed for cultural accuracy, relevance, and alignment with IEFA goals by the IEFA director at Hardin Middle School. This review has helped avoid superficial or symbolic inclusion of Native content and instead focus on learning experiences that are meaningful, accurate, and respectful, while demonstrating the relevance of Native knowledge to physical science education.

Because Native knowledge is place-based and use specific tribal histories, instructional materials should be adapted thoughtfully to local tribes. The lesson plans developed in this project are meant to be flexible and I encourage others to modify any part of them to reflect the knowledge, culture, and background of the tribes represented in their communities. When possible, educators should invite tribal voices into the classroom through guest speakers, interviews, or recorded stories. There is a great diversity among the tribes, so strategies, examples, and stories included in one lesson may not be appropriate for all communities. The goal of integrating Native knowledge into science instruction is not to replace Western science, but to present multiple ways of knowing.

CHAPTER FOUR

VALUE: REASONING AND REFLECTION

Introduction

The purpose of this project was to design a series of middle school physical science lessons that intentionally integrate Indigenous knowledge with Montana state standards to create more meaningful, relevant, and engaging science activities. By examining the value of the resources created for this project, we can see how they contribute to science teaching and learning, how they reflect the conceptual framework, and what implications they hold for the classroom, student learning, and the teaching profession.

Instructional Significance

The lessons created for this project are designed to address challenges in student engagement and relevance within traditional classrooms by providing a resource that can be integrated into existing curriculum while embedding culturally meaningful and place-based approaches. Many students experience science as disconnected from their lives. By integrating Native knowledge with physical science content, lessons are built with meaningful, place-based content. For example, instead of introducing abstract concepts like particle motion through textbook diagrams alone, students model atoms and molecules using beadwork patterns, allowing them to see how smaller parts connect to form larger systems. As a result of this place-based integration, students are more likely to see the purpose of their learning and become engaged in the process.

This project also addresses a significant gap in instruction: the underrepresentation of Indigenous knowledge in science classrooms. Science is often taught primarily through Western perspectives, which can unintentionally exclude or devalue knowledge from other sources. This project works to bridge that gap by embedding Native knowledge directly into the content. For instance, lessons incorporate examples such as tipi design for thermal energy, travois systems for force and motion, and traditional dye-making practices to explore chemical reactions, demonstrating that Indigenous knowledge systems involve observation, experimentation, and problem-solving. In doing so, it creates a more inclusive and accurate representation of how we understand the natural world.

In terms of student learning, this approach promotes understanding by connecting scientific ideas to real-world, place-based examples. It increases engagement through cultural activities by connecting scientific concepts to students' identities, lived experiences, and community knowledge, making learning more meaningful and relevant. For example, hands-on activities such as modeling molecules with beadwork patterns, investigating heat transfer through tipi design, creating natural dyes for pictographs, and exploring sound through drumming invite students to actively participate while recognizing the value of Indigenous knowledge systems in understanding science. Students also investigate non-contact forces through magnets and static electricity while connecting these ideas to observations of wind, gravity, and relationships in the natural world, reinforcing both scientific and cultural perspectives. The strategies within this project support critical thinking by encouraging students to consider multiple perspectives, and it gives students a sense of purpose in learning science. Additionally, it promotes cultural awareness and respect by positioning Native knowledge as a legitimate and valuable way of

understanding science. Together, these contributions demonstrate why these lessons are both meaningful and necessary.

Conceptual Implications

This project reflects the conceptual framework, which centers on three key ideas: that Indigenous knowledge is legitimate science, that it has been historically suppressed, and that it is necessary to intentionally include it within standards-based classrooms. Rather than simply stating these ideas, the resources put them into practice by embedding Indigenous perspectives within each lesson and aligning them with the standards.

One of the most significant strategies within the project is the use of inquiry. The lessons are structured using the 5E model, which requires students to actively engage with phenomena, investigate questions, collect data, and construct explanations. Inquiry is provided through hands-on activities and evidence-based reasoning. For example, in the energy lesson, students investigate how a stretched rubber band stores and releases energy before applying that understanding to tools like bows, connecting physical science concepts to cultural practices. Students are expected to develop their ideas using Claims, Evidence, Reasoning (CER), ensuring that they are actively participating in critical thinking.

The lessons also help students gain knowledge by moving away from memorization, building understanding through observation, investigation, and discussion, allowing them to connect new ideas to prior knowledge and experiences. Abstract concepts such as energy transfer, forces, and particle motion are made understandable by presenting them in familiar, place-based environments. For example, exploring how a tipi regulates temperature provides a concrete opportunity for students to understand heat transfer. Similarly, students explore wave

behavior by observing and feeling the vibrations of a drum, helping them connect amplitude and energy to a physical and cultural experience. This approach helps students move from concrete experiences to more abstract scientific reasoning.

Using this framework, students develop an understanding of scientific concepts by building relationships among ideas, experiences, people, and place. Learning occurs through interactions with classmates during investigations, guidance from Elders and community members, and connections to the local environment and cultural practices. These relationships are meaningful and help students organize and apply scientific knowledge. The lessons presented in this project encourage learning as a process of making connections between scientific ideas and the world students already know. In this way, understanding develops not only through acquiring new information but through strengthening relationships between prior knowledge, lived experience, and new scientific evidence.

This design demonstrates that scientific knowledge is constructed through place and experience. Students develop understanding by investigating phenomena that are familiar within their own environment and community so they can extend those understandings to broader scientific principles. For example, exploring heat transfer through the design of a tipi, investigating forces through a travois, or modeling energy transfer using a traditional bow provides experiences that make abstract scientific ideas meaningful. Place is not simply a setting; it is a resource that helps students observe patterns, ask questions, collect evidence, and construct explanations. As students connect classroom investigations to their own communities, scientific concepts become relevant and transferable to new situations.

Finally, this conceptual framework argues that incorporating multiple ways of knowing strengthens scientific reasoning rather than diminishing scientific rigor. Indigenous knowledge and Western science both value careful observation, pattern recognition, evidence, and explanation, although they may differ in how knowledge is developed and communicated. By engaging with both knowledge systems, students are encouraged to compare evidence, recognize multiple sources of understanding, and evaluate explanations using critical thinking. This requires students to unify ideas across different perspectives instead of relying on a single way of knowing. Rather than presenting Indigenous knowledge as an addition to science instruction, this framework positions it as essential.

Beyond increasing engagement, place-based, culturally inspired science instruction has the potential to change how students attain scientific understanding. Rather than learning science as a collection of isolated facts and formulas, students build understanding by connecting new scientific ideas to familiar places, cultural background, and lived experiences. For example, investigating thermal energy through the design of a tipi or modeling molecular structures with beadwork patterns allows students to develop scientific concepts through experiences that are meaningful in their local community. This approach helps students develop understanding by connecting abstract concepts to observable phenomena and familiar examples. By making these connections, students are encouraged to build knowledge actively instead of simply receiving information, resulting in a deeper understanding of the concepts and applications.

This project also suggests that integrating Indigenous knowledge with Western perspectives can strengthen student reasoning by encouraging examination of phenomena through multiple ways of knowing. Rather than viewing Indigenous knowledge and Western

science as competing systems, students learn that both rely on careful observation, evidence gathered over time, pattern recognition, and the development of explanations for natural phenomena. Multiple perspectives encourage students to compare evidence, recognize relationships, and consider how knowledge is shaped by culture, environment, and experience. When students recognize that scientific thinking exists within their own cultural traditions and local environment, science becomes more relevant and personally meaningful. Although this project does not evaluate student outcomes, the lesson design reflects current research suggesting that cultural and place-based instruction can increase engagement, strengthen understanding, and help students view themselves as capable in science learning.

Applying the conceptual framework in this way reveals that effective teaching is relational, relevant, and applies multiple ways of knowing. Effective teaching means intentionally building relationships with students and their communities, using those relationships to inform instruction that is meaningful. It requires designing learning experiences that connect academic content to students' cultural backgrounds, local environments, and lived experiences so that knowledge is not abstract, but has real-world context. Effective teaching also involves leading students through inquiry rather than delivering information, guiding students to construct understanding through investigation, discussion, and reflection. For example, rather than explaining Newton's Third Law directly, students experience it through canoes and push-off activities, then build their own explanations based on observed motion. In addition, it includes valuing and embedding multiple ways of knowing so that students see knowledge as interconnected and relevant. Finally, effective teaching requires ongoing reflection and adaptability, as teachers continuously adjust instruction to better support student engagement,

understanding, and a sense of belonging in the science classroom. This project demonstrates that integrating Native knowledge does not diminish scientific rigor; it enhances understanding by offering additional lenses through which students can interpret and apply scientific concepts. The framework was essential in guiding this work, as it provided a way of addressing the problem in a meaningful and intentional way.

Implications for Classroom Practice

This project has important significance for science teaching beyond a single classroom. It provides a model for how teachers can integrate culturally responsive, place-based learning with standards-aligned instruction in a way that enhances both engagement and rigor. This approach can be adapted across different content areas by focusing on the underlying structure rather than specific content.

Other teachers can implement this approach by using the 5E instructional model combined with inquiry-based strategies and CER assessments, while incorporating locally relevant phenomena and community knowledge. Rather than using the exact lessons, teachers can adapt the design by connecting scientific concepts to the culture, environment, and community of their own students. For example, a teacher might replace the tipi investigation with local housing structures or adapt the pictograph lesson to reflect materials and artistic practices specific to their region. This flexibility makes the project applicable to teachers anywhere. The project is particularly useful for middle school science teachers, educators working in rural or Native communities, and any teacher seeking to make science more inclusive and meaningful. However, its principles can extend to other grade levels and content as well.

Several instructional principles emerged from this work that can guide science teaching beyond these specific lessons. First, science concepts may be more likely to be understood when students are introduced to abstract scientific ideas through familiar environments, cultural practices, and local phenomena before applying those concepts to abstract content. By beginning with experiences that students recognize—such as the thermal properties of a tipi, the mechanics of a travois, or the chemistry of natural dyes—students are better able to connect concrete observations to scientific models. Place becomes a bridge that helps students transfer scientific understanding to new situations.

Second, cultural integration may strengthen scientific reasoning when students engage with multiple ways of knowing to investigate the same phenomenon. Rather than treating Indigenous knowledge as an enrichment activity, this framework positions it alongside Western scientific practices. Comparing and combining these perspectives encourages students to evaluate evidence critically, justify their thinking, and recognize that scientific understanding can be developed through multiple knowledge systems.

Third, inquiry-based learning promotes deeper understanding when students actively construct explanations rather than passively receive information. Throughout this project, students investigate phenomena, collect and analyze data, develop models, and communicate their thinking using Claim-Evidence-Reasoning (CER). These activities give students an opportunity to construct explanations based on evidence and meaningful experiences. Together, these principles suggest that rigorous science instruction is strengthened when learning is relational, place-based, cultural, and centered on inquiry. These principles provide a framework

that teachers can adapt across grade levels, disciplines, and communities while honoring the unique culture and backgrounds of their students.

Overall, this project suggests that students develop deeper understanding when scientific ideas are learned through meaningful experiences, local insight, and multiple ways of knowing. By positioning Indigenous knowledge as a complementary and rigorous perspective within science, the framework supports both scientific reasoning and students' sense of belonging in science classrooms.

Implications for Student Learning

This project highlights several important insights about how students learn science. It reinforces the idea that engagement and motivation are closely tied to relevance. When students see connections between scientific concepts and their own lives, communities, and environments, they are more likely to participate in the learning process.

The project supports deeper understanding by allowing students to learn through experience. Hands-on investigations, combined with opportunities to discuss and explain ideas, help students acquire more meaningful learning. The lessons are designed to change how students think about science, the goal is to challenge their old assumptions. For instance, students collecting temperature data from different structures or testing materials in wave investigations are actively building understanding rather than memorizing definitions. Additionally, by using the CER framework, we are guiding their reasoning development, teaching them how to back up a claim with solid evidence. This aligns with research presented in Chapter 2, which emphasizes the importance of active learning in science education. By connecting lessons to real-world

environments, we make it easier for students to take what they learned in the classroom and apply it to the real world.

The integration of Native knowledge furthers culturally relevant learning and supports students in developing an understanding of science. Students learn to value multiple perspectives and recognize that scientific knowledge is not limited to a single worldview. This can increase students' sense of belonging and identity within science, particularly for those whose cultural backgrounds are underrepresented.

Additionally, the emphasis on CER and inquiry-based learning strengthens students' scientific literacy. Students learn to use evidence to support their claims, communicate their reasoning, and engage in scientific argumentation. For example, students use CER to explain whether a chemical reaction occurred in the natural dye lab or to justify how energy is stored and transferred in a system. Collaboration and discussion further enhance this process, as students learn from one another and refine their thinking through shared experiences. Students learn best when they are actively engaged, culturally connected, and supported in understanding science through meaningful activities.

Thoughtful Modifications

Although these lessons were intentionally designed for students living on or adjacent to the Crow tribal lands, they are not intended to be implemented unchanged in other settings. Authentic place-based and culturally responsive instruction requires thoughtful adaptation to reflect the unique history, culture, environment, and knowledge systems of each local community. Every tribe has its own language, traditions, ecological knowledge, and relationships with the land; therefore, replacing Crow examples with those from another tribe should involve

consultation with tribal educators, Elders, or other cultural knowledge keepers whenever possible.

Teachers in non-Native communities should identify locally relevant phenomena, cultural resources, and environmental contexts that are meaningful to their own students rather than attempting to replicate Crow-specific lessons. The instructional framework presented in this project—including inquiry-based learning, the 5E instructional model, place-based investigations, and the integration of multiple ways of knowing—provides a flexible model that can be adapted while honoring the distinct identities and perspectives of individual communities. By maintaining the underlying principles rather than duplicating the specific cultural examples, educators can create learning experiences that are both scientifically rigorous and culturally authentic. Suggestions for thoughtful modification of the lessons have been given in Table 1.

Professional Reflection

This project led to significant professional growth by deepening understanding of how lesson design shapes student learning and reinforcing the importance of aligning instruction with both standards and student needs. One of the most important shifts in perspective was recognizing that integrating Native knowledge should not be treated as an addition to science teaching, but as an essential component of meaningful instruction. This required careful consideration of the knowledge represented in the curriculum and how to create space for multiple perspectives.

At the beginning of this project, I envisioned integration primarily as adding Native activities or cultural connections to one part of an existing science lesson, enriching the scientific content that had already been planned. Through the research and lesson design process, I came to

understand that authentic integration requires beginning with both the science standards and Indigenous knowledge systems as equally valuable foundations for learning. Rather than asking where a cultural example could fit into an existing lesson, I learned to ask how scientific concepts could be explored through local places, community knowledge, and culturally meaningful experiences from the outset. This shift changed my approach to curriculum design from simply including Indigenous perspectives to intentionally designing learning experiences in which multiple ways of knowing work together to deepen students' scientific understanding.

The project also increased awareness of the importance of relevance and connection in student engagement. Greater intentionality was applied in selecting phenomena, designing investigations, and structuring lessons in ways that reflect students' experiences. For example, selecting local phenomena such as wind, temperature differences, or community structures required intentional planning to ensure both scientific alignment and cultural relevance. Additionally, a deeper appreciation developed for inquiry-based learning and the role of the teacher as a facilitator rather than a provider of information. Overall, this work expanded understanding of what is possible in science education and provided new strategies for creating inclusive, engaging, and rigorous learning environments.

Future Directions

This project provides a foundation for continued development and extension. One potential direction is to use this approach with other science units, such as life science and earth science, where Native knowledge systems also offer valuable insights, although there are already quite a few resources available for these areas of study. The design could also be adapted for different grade levels, with modifications to meet the needs of younger or older students.

Another area for future work is refining and expanding the materials, including the development of additional lessons, assessments, and resources that support teachers in implementing this approach. Collaborating with community members and Elders could further strengthen the authenticity and depth of the lessons. Resources could also be designed with a focus on knowledge from different tribes.

Additionally, other instructional strategies could be integrated with these lessons to create more comprehensive and meaningful learning experiences. For example, incorporating collaborative group work, student-led discussions, and project-based learning could deepen student engagement and allow for more authentic application of scientific concepts. Technology integration, such as digital modeling or data collection tools, could also enhance investigation and analysis. Future research could examine the impact of this approach on student outcomes, including engagement, academic achievement, and attitudes toward science, as well as its influence on students' sense of identity and belonging in science learning environments.

While these lessons were developed using Crow knowledge and local examples from the Hardin community, the overall framework could be adapted to incorporate the knowledge, histories, and environmental perspectives of other Montana tribes. The process of beginning with science standards, identifying meaningful local connections, consulting tribal resources and community members, and designing place-based investigations can be applied in any tribal community. Future collaborations with tribal educators, Elders, and cultural specialists could support the development of similar physical science lessons that reflect the unique knowledge systems of tribes such as the Northern Cheyenne, Blackfeet, Salish, Kootenai, Assiniboine, Gros Ventre, Chippewa Cree, and others. Adapting the lessons in this way would further support the

goals of IEFA by honoring the diversity of Indigenous knowledge across Montana while maintaining rigorous science instruction.

The lessons could be shared through the Montana Office of Public Instruction (OPI) website as examples of standards-aligned science instruction that authentically incorporates Indian Education for All (IEFA). Presenting this work at professional development opportunities such as the Montana Federation of Public Employees (MFPE) Educators' Conference, the Montana Summer Science Institute, or the National Science Teaching Association (NSTA) conference would provide opportunities for educators to learn how to modify existing lessons to include Native knowledge and place-based learning. Sharing the lessons through these venues could help address the need for practical IEFA resources in physical science and encourage collaboration among teachers seeking to create more culturally responsive science classrooms.

Conclusion

In conclusion, this project demonstrates the value of integrating Indigenous knowledge with standards-based science instruction to create meaningful, engaging, and rigorous learning experiences. By connecting science to students' lives, communities, and environments, this approach enhances both understanding and engagement. This project also offers a model for more inclusive, relevant, and effective science teaching contributing to the ongoing evolution of science education.

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APPENDICES

APPENDIX A: MONTANA CODE ANNOTATED 2023

MONTANA CODE ANNOTATED

TITLE 20. EDUCATION

CHAPTER 9. FINANCE

Part 3. Funding of Basic System of Quality Public Schools

American Indian Achievement Gap Payment

20-9-330. American Indian achievement gap payment. (1) The state shall provide an American Indian achievement gap payment to public school districts, as defined in 20-6-101 and 20-6-701, for the purpose of closing the educational achievement gap that exists between American Indian students and non-Indian students.

(2) (a) The American Indian achievement gap payment is calculated as provided in 20-9-306, using the number of American Indian students enrolled in the district based on the count of regularly enrolled students on the first Monday in October of the prior school year as reported to the office of public instruction.

(b) A school district may not require a student to disclose the student's race.

(3) The district shall deposit the payment in the general fund of the district.

(4) The office of public instruction shall report to the governor and the legislature in accordance with 5-11-210 on the change in status of standardized test scores, graduation rates, and drop-out rates of American Indian students.

History: En. Sec. 4, Ch. 4, Sp. L. December 2005; amd. Sec. 18, Ch. 1, Sp. L. May 2007; amd. Sec. 3, Ch. 118, L. 2013; amd. Sec. 55, Ch. 261, L. 2021.

APPENDIX B: MONTANA MIDDLE SCHOOL
PHYSICAL SCIENCE STANDARDS

NGSS Identifier	NGSS Performance Expectation (PE)	Montana Science Content Standard	DCI	SEP	CCC	Adopted
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MS-PS1-2.	PE	analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred	PS1.A	Analyzing and Interpreting Data	Patterns	Yes
MS-PS1-5.	Develop and use a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved	develop, use, and critique a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved	PS1.B	Developing and using models	Energy and Matter	Adapted
MS-PS1-6.	PE	undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes	PS1.B	Constructing explanations (science) and designing solutions (engineering)	Energy and Matter	Yes
MS-PS3-1.	PE	construct and interpret graphic displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object	PS3.A	Analyzing and Interpreting Data	Scale, proportion and quantity	Yes
MS-PS3-2.	PE	develop and critique models to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system	PS3.A	Developing and using models	Systems and system models	Yes
MS-PS3-3.	PE	apply scientific principles to design, construct, and test a device that minimizes or maximizes thermal energy transfer	PS3.A	Constructing explanations (science) and designing solutions (engineering)	Energy and Matter	Yes
MS-PS3-4.	PE	plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample	PS3.A	Planning and carrying out investigations	Scale, proportion and quantity	Yes
MS-PS3-5.	PE	construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object	PS3.B	Engaging in Argument from Evidence	Energy and Matter	Yes
MS-PS2-1.	PE	apply Newton's Third Law of Motion to design a solution to a problem involving the motion of two colliding objects	PS2.A	Constructing explanations (science) and designing solutions (engineering)	Systems and system models	Yes

NGSS Identifier	NGSS Performance Expectation (PE)	Montana Science Content Standard	DCI	SEP	CCC	Adopted
MS-PS2-2.	PE	plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object	PS2.A	Planning and carrying out investigations	Stability and Change	Yes
MS-PS2-3.	PE	ask questions about data to determine the factors affecting electric and magnetic force strengths	PS2.B	Asking questions (science) and defining problems (engineering)	Cause and Effect	Yes
MS-PS2-4.	PE	construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the mass of interacting objects	PS2.B	Engaging in Argument from Evidence	Systems and system models	Yes
MS-PS2-5.	Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact	design and conduct an investigation to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact	PS2.B	Planning and carrying out investigations	Cause and Effect	Adapted
MS-PS1-1.	Develop models to describe the atomic composition of simple molecules and extended structures	develop and critique models that describe the atomic composition of simple molecules and extended structures	PS1.A	Developing and using models	Scale, proportion and quantity	Adapted
MS-PS1-3.	PE	gather information to describe that synthetic materials come from natural resources and impact society	PS1.A	Obtaining, evaluating and communicating information	Structure and Function	Yes
MS-PS1-4.	PE	develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed	PS1.A	Developing and using models	Cause and Effect	Yes
MS-PS4-1.	PE	use mathematical representations to describe a simple model for waves that includes how the amplitude and wavelength of a wave is related to the energy in a wave	PS4.A	Using mathematics and computational thinking	Patterns	Yes
MS-PS4-2.	PE	develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials	PS4.A	Developing and using models	Structure and Function	Yes
MS-PS4-3.	PE	Integrate qualitative scientific and technical information to support the claim that digitized signals are a more reliable way to encode and transmit information than analog signals.	PS4.C	Obtaining, evaluating, and communicating information	Structure and Function	Yes

APPENDIX C: MONTANA SCIENCE MODEL CURRICULUM

GUIDE BY GRADE LEVEL:

GRADES 6-8 PHYSICAL SCIENCE

Montana Science Model Curriculum Guide by Grade Level: Grades 6-8 Physical Science

September 2016



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Resources	Three Dimensions		
	Disciplinary Core Ideas (DCI's)	Science and Engineering Practices (SEP's)	Crosscutting Concepts (CCC's)
Paul Anderson Videos: Details on each component of the standards Next Generation Science Standards (NGSS) at National Science Teachers Association (NSTA) Hub: Detailed explanations of the three dimensions, videos of what it looks like in the classroom, curriculum guidance, and classroom resources Evidence Statements: Observations of what students should know and be able to do when they perform the standard. Helpful for formative and summative assessments The Framework: The framework for Montana Science Standards and for the Next Generation Science Standards NGSS Storylines: These storylines explain questions that students should investigating and how by grade level; they paint the big picture of the big ideas STEM Teacher Tools: This site has every resource necessary to implement the new standards Read more about the three dimensions in the NRC Framework online here (NGSS for States, By States)	Disciplinary core ideas have the power to focus K–12 science curriculum, instruction and assessments on the most important aspects of science. To be considered core, the ideas should meet at least two of the following criteria and ideally all four: - Have broad importance across multiple sciences or engineering disciplines or be a key organizing concept of a single discipline; - Provide a key tool for understanding or investigating more complex ideas and solving problems; - Relate to the interests and life experiences of students or be connected to societal or personal concerns that require scientific or technological knowledge; - Be teachable and learnable over multiple grades at increasing levels of depth and sophistication. Disciplinary ideas are grouped in four domains: the physical sciences; the life sciences; the earth and space sciences; and engineering, technology and applications of science.	The practices describe behaviors that scientists engage in as they investigate and build models and theories about the natural world and the key set of engineering practices that engineers use as they design and build models and systems. The National Research Council (NRC) uses the term practices instead of a term like “skills” to emphasize that engaging in scientific investigation requires not only skill but also knowledge that is specific to each practice. Part of the NRC’s intent is to better explain and extend what is meant by “inquiry” in science and the range of cognitive, social, and physical practices that it requires. Although engineering design is similar to scientific inquiry, there are significant differences. For example, scientific inquiry involves the formulation of a question that can be answered through investigation, while engineering design involves the formulation of a problem that can be solved through design. Strengthening the engineering aspects of the Next Generation Science Standards will clarify for students the relevance of science, technology, engineering and mathematics (the four STEM fields) to everyday life. (NGSS for States, By States).	Crosscutting concepts have application across all domains of science. As such, they are a way of linking the different domains of science. They include: Patterns, similarity, and diversity; Cause and effect; Scale, proportion and quantity; Systems and system models; Energy and matter; Structure and function; Stability and change. The Framework emphasizes that these concepts need to be made explicit for students because they provide an organizational schema for interrelating knowledge from various science fields into a coherent and scientifically-based view of the world. (NGSS for States, By States).

Grade 6-8 Physical Science			
Montana Standard <i>Students must know and be able to:</i>	Disciplinary Core Ideas (DCI's)	Science and Engineering Practices (SEP's)	Crosscutting Concepts (CCC's)
develop and critique models that describe the atomic composition of simple molecules and extended structures MS-PS1-1 , NGSS Identifier	PS1.A	developing and using models	scale proportion and quantity
analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred MS-PS1-2 , NGSS Identifier	PS1.A PS1.B	analyze and interpret data	patterns
gather information to describe that synthetic materials come from natural resources and impact society MS-PS1-3 , NGSS Identifier	PS1.A PS1.B	obtaining, evaluating, and communicating information	structure and function
develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed MS-PS1-4 , NGSS Identifier	PS1.A PS3.A	developing and using models	cause and effect
develop, use, and critique a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved MS-PS1-5 , NGSS Identifier	PS1.B	developing and using models	energy and matter: flows, cycles and conservation
undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes MS-PS1-6 , NGSS Identifier	PS1.B ETS1.B ETS1.C	construct explanations and design solutions	energy and matter: flows, cycles and conservation

apply Newton's Third Law of Motion to design a solution to a problem involving the motion of two colliding objects MS-PS2-1 , NGSS Identifier	PS2.A	construct explanations and design solutions	system and system models
plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object MS-PS2-2 , NGSS Identifier	PS2.A	planning and carrying out investigations	stability and change
ask questions about data to determine the factors affecting electric and magnetic force strengths MS-PS2-3 , NGSS Identifier	PS2.B	asking questions and defining problems	cause and effect
construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the mass of interacting objects MS-PS2-4 , NGSS Identifier	PS2.B	engaging in argument from evidence	system and system models
design and conduct an investigation to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact MS-PS2-5 , NGSS Identifier	PS2.B	planning and carrying out investigations	cause and effect
construct and interpret graphic displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object MS-PS3-1 , NGSS Identifier	PS3.A	analyze and interpret data	scale proportion and quantity

develop and critique models to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system MS-PS3-2 , NGSS Identifier	PS3.A PS3.C	developing and using models	system and system models
apply scientific principles to design, construct, and test a device that minimizes or maximizes thermal energy transfer MS-PS3-3 , NGSS Identifier	PS3.A PS3.B ETS1.A ETS1.B	construct explanations and design solutions	energy and matter: flows, cycles and conservation
plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample MS-PS3-4 , NGSS Identifier	PS3.A PS3.B	planning and carrying out investigations	scale proportion and quantity
construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object MS-PS3-5 , NGSS Identifier	PS3.B	engaging in argument from evidence	energy and matter: flows, cycles and conservation
use mathematical representations to describe a simple model for waves that includes how the amplitude and wavelength of a wave is related to the energy in a wave MS-PS4-1 , NGSS Identifier	PS4.A	using mathematics & computational thinking	patterns
develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials MS-PS4-2 , NGSS Identifier	PS4.A PS4.B	developing and using models	structure and function

APPENDIX D: LESSON ALIGNMENT WITH MONTANA
MIDDLE SCHOOL PHYSICAL SCIENCE STANDARDS

Table 5. Lesson Alignment with Montana Middle School Physical Science Standards.

Standard(s)	Lesson Summary	Modification Suggestions
Lesson 1: Everything Is Connected – Modeling Matter Through Relationships		
MS-PS1-1: develop and critique models that describe the atomic composition of simple molecules and extended structures.	Elder: Discover Fred Begay (Clever Fox), physicist who showed how native knowledge supported him as a scientist.	Clever Fox is Navajo but is inspirational to all cultures
	Engage: Students compare the patterns they see in beadwork, elk tooth dresses, and snowflake images to patterns in the periodic chart. These patterns will help students recognize how complex objects are made from smaller, connected parts.	Consider patterns important in the specific culture or community: leatherwork, beadwork, rugs, fabrics, carvings, etc.
	Explore: Students build models of atoms using beads to represent subatomic particles and their connections.	Materials other than beads could be used to create an atom model.
	Environment: Students compare their models to patterns found in nature, such as crystals or plant structures.	Choose natural items found in the specific area.
	Explain: Students describe their models and describe the patterns they see. Students will discover how everything can be divided into the smallest parts of atoms and molecules which shows how everything is linked together, and how we are connected to the natural world on an atomic level.	This activity is relevant in all communities and cultures.
	Elaborate: Students expand their models to show how their atoms connect to form ionic and covalent bonds.	This activity is relevant in all communities and cultures.
	Evaluate: Students use the Claims, Evidence, Reasoning (CER) format to answer the following guiding question: <i>“How do the patterns we see in the periodic table determine the properties of matter?”</i>	This activity is relevant in all communities and cultures.

Lesson 2: Chemistry in Natural Dyes and Pictographs		
MS-PS1-2: analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.	Engage: Students observe a color-changing pH indicator and pictograph images to question why materials change color and whether new substances are formed.	Try to find pictograph images from locations near the specific community.
	Elder: An Elder shares how natural materials were traditionally tested and selected for dyes and paints.	Ask an Elder from your community to discuss their traditional dyes and paints.
	Explore: Students rotate through lab stations to test color changes, observe gas production, combine materials to form a precipitate, and measure temperature changes during chemical reactions.	This activity is relevant in all communities and cultures.
	Environment: Students travel to Pictograph Cave to observe the cave drawings that have been there for thousands of years.	Visit a location that has pictograph paintings near the specific community.
MS-PS1-5: develop, use, and critique a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved.	Explain: Students create paints from local minerals, plants, charcoal and clays.	This activity is relevant in all communities and cultures.
	Elaborate: Students create pictographs using their paints and test the pigments over time in the sun.	This activity is relevant in all communities and cultures.
	Evaluate: Students use the Claims, Evidence, Reasoning (CER) format to answer the following guiding question: <i>“How do we know that a chemical reaction has occurred in pictographs?”</i>	This activity is relevant in all communities and cultures.

Lesson 3: Natural Resources, Synthetic Materials		
MS-PS1-3: gather information to describe that synthetic materials come from natural resources and impact society.	Engage: Students examine everyday objects and discuss whether they are natural or synthetic.	Choose natural materials traditionally used in the specific community.
	Elder: An Elder describes the changes through the years of materials used to create regalia.	Ask an Elder to explain how a materials used to make specific item in their culture has changed with the use of synthetic materials.
	Explore: Students rotate through stations to sort materials and test natural materials to compare properties.	Choose natural materials traditionally used in the specific community.
	Explain: Students learn that synthetic materials are made from natural resources and analyze differences in properties, uses, and impacts.	This activity is relevant in all communities and cultures.
	Elaborate: Students design a material that meets human needs while considering environmental impacts.	This activity is relevant in all communities and cultures.
	Evaluate: Students use the Claims, Evidence, Reasoning (CER) format to answer the following guiding question: <i>“How do synthetic materials affect the environment?”</i>	This activity is relevant in all communities and cultures.

Lesson 4: Heat, Shelter, and Balance – Understanding Thermal Energy		
MS-PS1-4: develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.	Engage: Students compare a modern house, a tipi, and a sweat lodge to question how different structures control heat.	Sweat lodges are still used by the Crow Tribe today. Tipis were the predominant shelter for the Crow. If sweat lodges or tipis are not used in the specific community, use examples of traditional shelters.
	Elder: An Elder shares knowledge about tipis and how they respond to outdoor temperature.	Have an Elder discuss how their traditional shelters were heated.
MS-PS1-6: undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes.	Environment: Students discuss animal homes to consider how heat is managed in their environment.	If the animals selected for this activity are not indigenous to the area, find articles about animals that are.
	Explore: Students investigate the difference in heat retention between a tipi and a home.	If tipis are not used in the specific community, build models of traditional shelters.
	Explain: Students learn how thermal energy affects particle motion.	This activity is relevant in all communities and cultures.
MS-PS3-3: apply scientific principles to design, construct, and test a device that minimizes or maximizes thermal energy transfer.	Elaborate: Students design and test a device based on Native technologies that controls heat, using data to improve their design.	Describe local tribal insulation technologies for students to replicate.
	Evaluate: Students use the Claims, Evidence, Reasoning (CER) format to answer the following guiding question: <i>“How does thermal energy move, and how can a design reduce heat transfer?”</i>	This activity is relevant in all communities and cultures.

Lesson 5: For Every Action – Reaction		
MS-PS2-1: apply Newton's Third Law of Motion to design a solution to a problem involving the motion of two colliding objects.	Engage: Students observe a canoe as it is propelled through the Big Horn.	Find a video of a traditional water transport vehicle for the specific area.
	Explore: Students investigate action-reaction forces through collisions, push-off, and canoe activities while collecting data on motion. Students use a canoe in a pond or the school pool to investigate action-reaction forces.	Use a traditional water transport vehicle for the specific area.
	Environment: Students connect their findings to movement in natural settings like animals running, flying, or swimming.	If the animals in the videos are not indigenous to the specific area, find videos of animals that are.
	Explain: Students learn that forces always come in equal and opposite pairs acting on different objects and apply this to their observations while playing Doubleball.	Doubleball is a game of the Plains Indians. Consider other games that are from the specific area.
	Elaborate: Students design and test a system that controls motion during a collision using their understanding of action–reaction forces.	Show students examples of transport technologies from the specific area.
	Evaluate: Students use the Claims, Evidence, Reasoning (CER) format to answer the following guiding question: <i>“How does Newton's Third Law explain why both objects move during an interaction?”</i>	This activity is relevant in all communities and cultures.
	Elder: An Elder reflects on how both scientific and Indigenous perspectives explain motion through relationships.	This activity is relevant in all communities and cultures.

Lesson 6: Forces and Motion – Learning from Tipis and Travois		
MS-PS2-2: plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.	Engage: Students observe a tipi in wind and a travois carrying weight to question how forces affect stability and motion.	Share with students that if tipis are not the traditional shelter of the specific area, this activity will not reflect the local community. If a travois is not the way cargo was transported, consider modeling a traditional vehicle of the specific area.
	Explore: Students build tipi models, pull weighted travois systems, and test motion on ramps to collect data on force, mass, and energy.	Share with students that if tipis are not the traditional shelter of the specific area, this activity will not reflect the local community.
MS-PS3-1: construct and interpret graphic displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object.	Environment: Students improve their travois to optimize stability, efficiency, or energy transfer.	If a travois is not the way cargo was transported, consider modeling a traditional vehicle of the specific area.
	Explain: Students learn that motion depends on net force and mass, and that kinetic energy depends on mass and speed.	This activity is relevant in all communities and cultures.
	Elaborate: Students design and improve a tipi to optimize stability.	Share with students that if tipis are not the traditional shelter of the specific area, this activity will not reflect the local community.
	Evaluate: Students use the Claims, Evidence, Reasoning (CER) format to answer the following guiding question: <i>“How do force and mass affect an object's motion and kinetic energy?”</i>	This activity is relevant in all communities and cultures.
	Elder: An Elder demonstrates how tipis were designed, building a tipi on the practice field.	If tipis are not the traditional shelter of the specific area, ask Elder to discuss their traditional shelter.

Lesson 7: Forces We Cannot See		
MS-PS2-3: ask questions about data to determine the factors affecting electric and magnetic force strengths.	Engage: Students observe magnets, static electricity, gravity, and drum vibrations to ask how objects can move or affect each other without touching.	Not all tribes use pow wow drums. If the specific area does not have this tradition, inquire as to what other type of drum you could use.
	Elder: An Elder discusses interconnected relationships between Earth, sky, water, and living beings.	This activity is relevant in all communities and cultures.
MS-PS2-4: construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the mass of interacting objects.	Explore: Students rotate through stations (magnetism, static electricity, gravity models) to investigate how distance, mass, and materials affect non-contact forces.	Research the significance of directions in your specific area. Use hides of animals indigenous to the specific area. Research how local tribes use irrigation.
	Environment: Students discover how animals use magnetoreception to navigate.	This activity is relevant in all communities and cultures.
MS-PS2-5: design and conduct an investigation to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact.	Explain: Students share data and learn that non-contact forces act through fields, and that force strength depends on distance, mass, and object properties.	This activity is relevant in all communities and cultures,
	Elaborate: Students design a magnetic deadfall trap showing non-contact forces and explain it using both scientific concepts and ideas of balance and connection.	If the local area Indigenous people do not use deadfall traps, consider modifying this challenge to model a local traditional trap.
	Evaluate: Students use the Claims, Evidence, Reasoning (CER) format to answer the following guiding question: <i>“How can an object change the motion of another object without ever physically touching it?”</i>	This activity is relevant in all communities and cultures.

Lesson 8: Energy in Relationships – Potential, Motion, and Transfer		
MS-PS3-2: develop and critique models to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system.	Engage: Students observe a stretched rubber band and falling objects to question where energy is stored before motion occurs.	Note: Although widespread, not all tribes used bows and arrows.
	Elder: An Elder shares how tools like bows demonstrate stored and transferred energy.	This activity is relevant in all communities and cultures.
	Explore: Students investigate how a bow and arrow transfer potential energy, thermal energy, and kinetic energy through hands-on stations while collecting data on energy changes.	Note: some tribes restrict female use of weapons. Research local traditions.
MS-PS3-4: plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample.	Explain: Students learn that energy is stored based on position and arrangement and transferred through motion and interactions between objects by comparing traditional weapons.	The weapons compared in this activity are used by the Crow tribe. Research local traditional weapons.
	Elaborate: Students compare clean energy to fossil fuels using Hopi perspectives. Students then use technology to build a light sensor with solar panels.	If you do not have access to the Climate Action Kits. The content in the AISES FIIRE lesson is still relevant.
	Environment: Students list local examples of potential energy and explain how they transfer to kinetic energy.	This activity is relevant in all communities and cultures.
MS-PS3-5: construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.	Evaluate: Students use the Claims, Evidence, Reasoning (CER) format to answer the following guiding question: <i>“How does changing the properties of a bow and arrow change how potential energy transforms to kinetic energy?”</i>	This activity is relevant in all communities and cultures.

Lesson 9: Observing Waves, Energy, and Light Through a Lens of Culture and Science		
MS-PS4-1: use mathematical representations to describe a simple model for waves that includes how the amplitude and wavelength of a wave is related to the energy in a wave.	Engage: Students observe and listen to a powwow drum and light demonstrations to question how waves carry energy and interact with materials.	Not all tribes use pow wow drums. If the specific area does not have this tradition, inquire as to what other type of drum you could use.
	Elder: An Elder shares the cultural significance of drum sound and how it connects people across distance.	Research traditional communication methods of the local area to use in this activity.
MS-PS4-2: develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.	Explore: Students investigate sound waves using a drum model and explore light behavior through hands-on testing with different materials and art design.	This activity is relevant in all communities and cultures that use any type of drums.
	Explain: Students learn that amplitude relates to energy and that waves can be reflected, absorbed, or transmitted depending on materials.	This activity is relevant in all communities and cultures that use any type of drums.
	Elaborate: Students create a design using cyanotype paper after viewing the buffalo hide designed with this process by a Rocky Boy artist.	This activity is relevant in all communities and cultures.
	Environment: Students investigate why snow reflects more sunlight than soil.	This activity is relevant in all communities and cultures.
	Evaluate: Students use the Claims, Evidence, Reasoning (CER) format to answer the following guiding question: <i>“How does amplitude affect the energy carried by a wave, and how do different materials affect the movement of light waves?”</i>	This activity is relevant in all communities and cultures.

APPENDIX E: PHENOMENA USED FOR EACH LESSON

Table 6. Phenomena Used for Each Lesson.

Lesson Number	Topic	Phenomena
1	Everything Is Connected – Modeling Matter Through Relationships	Objects like beadwork, elk tooth dresses, and snowflakes are made of repeating patterns built from smaller parts. Similarly, all matter is made of atoms that combine in specific ways to form molecules and larger structures.
2	Chemistry in Natural Dyes and Pictographs	Natural dyes, like red cabbage juice, change color when mixed with different substances, and reactions like vinegar and baking soda produce bubbles. These changes suggest that new substances may form.
3	Natural Resources, Synthetic Materials	Everyday objects like plastic bottles, clothing, and rubber items look very different, but all come from natural resources that have been processed in different ways. This raises the question of how materials are made and how those choices affect people and the environment.
4	Heat, Shelter, and Balance – Understanding Thermal Energy	Very different structures, like a modern insulated house and a tipi, can both keep people warm by controlling how heat moves. This shows that different designs can manage thermal energy using similar concepts.
5	For Every Action – Reaction	When two objects interact, like a canoe paddle in water, both objects move, even if only one seems to cause the motion. This shows that forces always occur in pairs, acting in opposite directions.
6	Forces and Motion – Learning from Tipis and Travois	A tipi remains stable in strong wind while a travois becomes harder to pull as more weight is added. These situations show how forces, mass, and motion interact in real-world systems.
7	Forces We Cannot See	Relationships are not always visible, but non-contact forces can move objects without touching, such as

		magnets pulling paper clips, balloons sticking to walls, and the Moon affecting tides.
8	Energy in Relationships – Potential, Motion, and Transfer	When a stretched rubber band is released or an object is dropped, stored energy is converted into motion. This shows that energy can be stored in systems based on position and then transferred when the position changes.
9	Observing Waves, Energy, and Light Through a Lens of Culture and Science	The sound of a powwow drum can be both heard and felt, and light changes when it interacts with different materials. These phenomena show that waves carry energy and behave differently depending on their amplitude and the materials they encounter.

APPENDIX F: PLACE-BASED LEARNING
USED FOR EACH LESSON

Table 7. Place-Based Learning Used for Each Lesson.

Lesson Number	Topic	Place-Based Learning
1	Everything Is Connected – Modeling Matter Through Relationships	Patterns in beadwork, weaving, and nature reflect relationships that create meaning and function. These same ideas of pattern and connection help explain how atoms form matter in the natural world.
2	Chemistry in Natural Dyes and Pictographs	Native peoples use plants, minerals, and charcoal to create dyes and pictographs, observing how materials change under different conditions.
3	Natural Resources, Synthetic Materials	Native communities use locally available materials like hides, plants, and wood. Comparing these practices to modern synthetic materials helps students understand how these materials impact local environments.
4	Heat, Shelter, and Balance – Understanding Thermal Energy	Native communities designed shelters like tipis based on climate, airflow, and available materials to manage heat effectively. These designs reflect deep knowledge of how thermal energy moves in real environmental conditions.
5	For Every Action – Reaction	Movement through water and land depend on pushing against something to create motion. Native technologies like canoes reflect an understanding of these force relationships through observation and experience.
6	Forces and Motion – Learning from Tipis and Travois	Tipis and travois were designed using deep knowledge of wind, land, and movement to ensure safety, efficiency, and mobility.
7	Forces We Cannot See	Native people have observed how wind, water, land, and sky interact across distance. These observations reflect an understanding that relationships and forces shape movement and balance in the natural world.

8	Energy in Relationships – Potential, Motion, and Transfer	Energy relationships are observed in tools like bows, in gravity affecting movement across land, and in heating practices using stones and fire. These examples reflect how energy moves from place to place.
9	Observing Waves, Energy, and Light Through a Lens of Culture and Science	Sound (like drumming) represents connection and can travel across distance, while light and color are used in art and storytelling. These practices reflect an understanding of how waves move energy and interact with the environment.

APPENDIX G: CLAIMS, EVIDENCE REASONING
GRAPHIC ORGANIZER

Claims, Evidence and Reasoning Graphic Organizer

What is your scientific question?	
CLAIM A statement or conclusion that answers the scientific question;	
Photo or sketch	
EVIDENCE A subset of the scientific data that supports the claim.	
	Photo or sketch
REASONING An explanation or justification that connects the evidence to the claim.	
Photo or sketch	

APPENDIX H: CLAIMS, EVIDENCE REASONING
ASSESSMENT USED FOR EACH LESSON

Table 8. Claims, Evidence, Reasoning Assessment Used for Each Lesson.

Lesson Number	Topic	Claims, Evidence, Reasoning Assessment (Claim given to students)
1	Everything Is Connected – Modeling Matter Through Relationships	Matter is made of atoms that combine in specific patterns using chemical bonds. The way atoms are arranged determines the properties of the material.
2	Chemistry in Natural Dyes and Pictographs	We know chemical reactions have occurred when substances change color, change odor, form a precipitate, form bubbles, change temperature, or give off light.
3	Natural Resources, Synthetic Materials	Synthetic materials affect the environment because they are made from natural resources. Synthetic materials provide useful products for society, but they can also contribute to pollution and waste in the environment.
4	Heat, Shelter, and Balance – Understanding Thermal Energy	Thermal energy moves through conduction, convection, and radiation, and insulation can reduce heat transfer.
5	For Every Action – Reaction	For every action force, there is an equal and opposite reaction force acting on a different object.
6	Forces and Motion – Learning from Tipis and Travois	The motion of an object depends on the amount of force acting on it and its mass. Kinetic energy increases as an object's mass or speed increases.
7	Forces We Cannot See	Non-contact forces move objects across a distance because the source object creates an invisible field that stores energy and exerts a push or pull on any interacting object that enters its boundaries.
8	Energy in Relationships – Potential, Motion, and Transfer	Modifying the bow's properties like type of wood or how far you pull the string causes varying amounts of potential energy to be converted into kinetic energy.

9	Observing Waves, Energy, and Light Through a Lens of Culture and Science	Greater amplitude produces waves with more energy, and materials interact with light by reflecting, absorbing, or transmitting the wave depending on their properties.
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APPENDIX I: NINE LESSONS
ALIGNING INDIGENOUS KNOWLEDGE WITH
MONTANA'S MIDDLE SCHOOL
PHYSICAL SCIENCE STANDARDS

The following are links to the nine lessons created for this project.

[Lesson Plan 1: Everything Is Connected – Modeling Matter Through Relationships](#)

[Lesson Plan 2: Chemistry in Natural Dyes and Pictographs](#)

[Lesson Plan 3: Natural Resources, Synthetic Materials](#)

[Lesson Plan 4: Heat, Shelter, and Balance – Understanding Thermal Energy](#)

[Lesson Plan 5: For Every Action – Reaction](#)

[Lesson Plan 6: Forces and Motion – Learning from Tipis and Travois](#)

[Lesson Plan 7: Forces We Cannot See](#)

[Lesson Plan 8: Energy in Relationships – Potential, Motion, and Transfer](#)

[Lesson Plan 9: Observing Waves, Energy, and Light Through a Lens of Culture and](#)

[Science](#)