

LITERATURE REVIEW

STEM EDUCATION FOR NATIVE AMERICAN STUDENTS



Produced by:

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INTRODUCTION

The American Indian Science and Engineering Society (AISES) was awarded a National Science Foundation Education Core Research grant (Award: 1561768), titled *Capacity building: understanding American Indian, Alaska Native, and Native Hawaiian student outcomes in the STEM education research literature*. The purpose of the literature review is to develop an understanding of the strategies known to improve the educational outcomes of Native students. This scoping literature review will focus primarily on the primary and secondary education of Native students to include American Indian, Alaska Native, Native Hawaiian, First Nations, and other Indigenous peoples. The findings from the literature review will guide AISES in developing its own educational strategies and programmatic offering and build the capacity of AISES to serve as a source of knowledge and expertise in this field. AISES intends to continue reviewing the literature and engaging in research on STEM education for Native students. This report concludes with recommendations for future directions in both instruction and research.



BACKGROUND

The literature review stems from a longstanding need to address the educational disparities facing Native students. The educational disparity of American Indian and Alaska Native (AI/AN) students in the United States begins in elementary school and continues into high school where only 72% of AI/AN students in 2017-2018 graduated high school, the lowest graduation rate of any race/ethnicity (McFarland et al 2018; Blueprint for Reform Implementation n.d.). Furthermore, Bureau of Indian Education (BIE) schools, enrolling about 8% of AI/AN students, report only a graduate rate of 53%, both of these statistics are far below the national average graduate rate of 84% (McFarland et al 2018). Even for the AI/AN students who graduate from high school, most are often underprepared for college. AI/AN students often attend schools that are underfunded and ill-equipped to prepare them for college entrance or a successful college experience. Inevitably these disparities compound into diminished interest in higher education with only 23% of AI/AN students aged 18 to 24 enrolling in college in 2014-2015, down from 35% in 2013-14. For AI/AN students who do attend college, in 2008, only 23% of first-time, full-time AI/AN students graduate within 4 years, compared to 44% of white students (McFarland 2017).

Particularly in the fields of science, technology, engineering, and math (STEM), AI/AN college students are severely underrepresented, leading to even more dramatic underrepresentation in the STEM workforce. This underrepresentation is due at least in part to the lack of development of interest in STEM disciplines during grade school and to a related lack of proficiency in STEM subjects. In 2015 AI/AN students had lower National Assessment on Educational Progress (NAEP) mathematics scores than other racial/ethnic groups, besides Black students, in grades 4 and 8. Furthermore, the gap between AI/AN NAEP mathematics scores and White scores increased from grade 4 to grade 8 by 4 points, from 21 to 25, the largest gap second only to Black students (Musu-Gillette et al 2017).

In addition to proficiency issues in elementary and middle school, fewer than half of AI/AN high school students have the full range of math and science courses available at their school to prepare them for college entrance exams, and only one in four AI/AN students who take the American College Test (ACT) score at the college ready level in math (Condition of College & Career Readiness 2012). Therefore, it is easy to understand why AI/AN college students select majors in Science and Engineering (S&E) fields at rates far less than their non-Native (particularly White) counterparts. According to the National Science Foundation (NSF) in 2014, 40% of White or Caucasian Freshmen intended to major in S&E fields, while only 30% of AI/AN students declared the same (Rivers 2017). While more and more underrepresented students are starting college with plans to major in STEM fields, completion rates for underrepresented minorities continue to lag behind. One third of White students and 42% of Asian-American students who started college as intended STEM majors graduated with STEM degrees by the end of five years. For underrepresented minorities, the five-year completion rates were much lower -- 22.1% for Latino students, 18.4% for African American students and 18.8% for AI/AN students (Epstein 2010).

Although these outcomes reflect the negative status of Native student education outcomes, they fail to illuminate the many successes, examples of education sovereignty in practice, and the myriad strategies for improving education for Native students, especially in STEM fields. AISES like many others strive to focus not on deficits but instead on the assets and wealth of knowledge and ways of knowing and being in the world that Native students, communities, and cultures possess and have possessed since time immemorial. Therefore, AISES sought to conduct a literature review aimed at understanding strategies for supporting educational success among Native students in STEM rather than discussions of deficits, challenges, and barriers.



METHODS

Dr. Kathy DeerInWater, AISES Chief Program Officer, conducted a scoping literature review on STEM education for Native students. The literature review focused primarily on secondary, formal and informal education rather than higher education. The goal of the literature review was to provide an understanding of the most effective educational strategies for Native learners in the areas of STEM. The literature review sought to compile case studies, reviews, and qualitative and quantitative research on STEM education and learning for Native students, including teaching methods.

The following procedures were used to conduct the literature review:

- 1) Search engines including Web of Knowledge and Google Scholar were used concurrently to identify relevant, published articles.
- 2) The literature review focused primarily on primary research articles published in peer-reviewed journals and included books and book chapters.
- 3) Searches were conducted using the following keywords and combinations:
 - a. These words were used to identify the target group: American Indian, Native American, Alaska Native, Native Hawaiian, and Indigenous
 - b. These words were used to identify the research field: STEM, Science, Technology*, Engineer*, Math*, Education, Learning, and Teaching.
- 4) Once identified, journal articles were saved and sorted into meaningful categories, often based on the keyword searches used to find the article.
- 5) Journal articles were then reviewed, and references cross listed to identify additional articles relevant to the literature review.

In addition to the literature review, Dr. DeerInWater convened a small group of leading STEM education researchers, comprised of Native researchers or those whose research focused on Native learners. The group met in early 2019 to discuss the literature around STEM education for Native students; however, the discussion focused more prominently on strategies and recommendations, which stem from the researchers' experiences and are echoed in the more recent literature.



RESULTS

Throughout the literature on the topic of STEM education for Native learners is the pervasive notion of science education as devoid of culture, a set of universal principals to be memorized, and removed from context (Aikenhead, 2018). It is the promoting of Eurocentric science as the acultural, ultimate truth, based on empirical data, that excludes individual experiences, different ways of knowing, and histories (Brandt 2008; Bang and Medin, 2010). However, Aikenhead (1997) recognized Western science as a subculture of Euro-American culture; within this cultural framework, learning Western science is an act of cultural acquisition. Aikenhead (1997) argues that failing to recognize teaching and learning as cultural transmission and acquisition, prevents viewing science education as a tool for Western prestige, power, and progress threatening Indigenous cultures. Navigating Western science then requires indigenous students to cross cultural borders from the subcultures of their friends, family, and Nation to the subcultures of school and Western science. Bang and Medin (2010), argue that science instruction is too often not recognized as a set of cultural practices, removing the practice of science from everyday life. This divide between school and life outside of school may further separate Native student's beliefs, experiences, and knowledge, devaluing their contributions to the classroom (Bang and Medin 2010). Snively and Williams (2008) argue

every culture has its own science knowledge system and all have been valuable and useful to the cultures developing them, positing science education must become more inclusive of different cultures' definitions and metaphors of science.

Once recognized as reflecting dominate culture, Western science education is widely seen as in conflict with indigenous cultures and science. Further undermining the success of Native students in mainstream science education, is the cultural conflict between Native cultures and values (i.e. reciprocity, relationship, ritual, respect, relevance reverence, and repetition) and those of Western science (Allen 1997; Matthews and Smith 1994; Biin and Weston 2015). Not only is Eurocentric science content exclusionary but the teaching of these principles further excludes students by failing to understand or include community norms and values, particularly among Native communities (Nelson-Barber and Estrin 1995). In regard to mathematics, Aikenhead (2018) found most Indigenous students' worldviews and the dominant worldview of mathematics was an obstacle for those students. For example, conventional mathematics deals with thinking only of content, whereas indigenous mathematizing deals with thinking, doing, living, and being with the content (Aikenhead 2018).



In addition, the opposition of Western science and Indigenous science, formal education in general, has sought to systematically and intentionally control and assimilate Indigenous children; the educational colonization of American Indians is not a new concept (Davis 2001, Bang and Medin 2010; Dupuis and Abrams 2017). Similarly, Simpson (2014) suggests without considerable intervention, state education systems are primarily designed to maintain settler colonialism. Re-thinking curricula to integrate Indigenous knowledge and provide place-based, culturally responsive instruction is critical to decolonizing STEM education (Aikenhead and Elliott 2010).

To combat this history, Tribal Nations have called for improving the education of Native students since the early part of the twentieth century. Culturally responsive schooling is education that makes sense to students who are not members of, or assimilated into, the dominant social group (Klung and Whitfield 2003). Culturally responsive teaching is not new and has been widely viewed as a promising strategy for improving the education and achievement of Native students across the country (Brayboy and Castagno 2008). Brayboy and Castagno (2008) provide an excellent summary of the positive effects of culturally responsive teaching on Indigenous youth including:

“Students who have enhanced self-esteem (Agbo 2004; Cleary and Peacock 1998), develop healthy identity formation (Trujillo et al 2002), are more self-directed and politically active (Garcia and Ahler 1992), give more respect to tribal elders (Agbo 2004), have a positive influence in their tribal communities (Cleary and Peacock 1998; Department of Education 2001; Pewewardy 1998), exhibit more positive classroom behavior and engagement (Cleary and Peacock 1998; Lipka 1990), and achieve academically at higher rates (Apthorp et al 2002; Demmert 2001; Demmert and Towner 2003; Klump and McNeir 2005; Smith et al 1998; Swisher and Tippeconnic 1999; Taylor et al 1991; Zwick and Miller 1996). A smaller body of scholarship points to the importance of recognizing all voices in the classroom and ensuring that Indigenous students are not silenced in the schooling process (Belgarde et al 2002), which in turn leads to more meaningful educational experiences and student empowerment (Gay 2000; Nieto 2004; Reyhner 1992).” (pg. 5)

The importance of culturally relevant teaching for American Indian students is further explained by American Indian educators (e.g. Cleary and Peacock 1998; Demmert and Towner 2003; Gilbert 2011). Nam et al (2013) also shares the different terms used for culturally relevant education, such as culturally oriented education (Mahan 1981), culturally based education (Demmert and Towner 2003; Gilbert 2011), and culturally congruent instruction. All of these methods stress the importance of considering American Indian students’ learning and communication styles (Morgan 2010), using native language (Demmert and Towner 2003; Gilbert 2011; Morgan 2010), using instructional methods that value cultural teaching methods (Preston 1991), and community participation and use of community customs and values (Demmert and Towner 2003).

Many argue culturally relevant education must include a grounding in Indigenous ways of knowing (i.e. Indigenous knowledge, Indigenous epistemologies). Cajete (1994) advocates for developing Indigenous education as contemporary, culturally-based education rooted in traditional tribal values, orientations, and principles. Kawagley et al (1998) report that Indigenous cultures, knowledge, and epistemologies can serve as a culturally relevant context for teaching Indigenous students.

As indicated, there is a considerable body of literature on the need, methods, and impact of culturally relevant education for Native students rooted in Indigenous knowledge. Given Indigenous knowledge is part of the “collective genius of humanity of Indigenous people” stemming from their learning and knowing of the world around them (Battiste 2009), the next logical step is to connect the importance of culturally relevant STEM education for Native students.





INDIGENOUS KNOWLEDGE AND INDIGENOUS SCIENCE

Mack et al (2012) outlines effective ways of using Native ways of knowing to strengthen Informal Science Education (ISE) programs, providing the following practices and recommendations from a Consensus Advisory Committee:

- “Create hands on, inquiry-based lessons that reflect the people in their aboriginal homeland.
- Use the community as an integral resource in developing curriculum and instruction.
- Use Native language to facilitate instruction and to promote the Native worldview
- Match the values of the program to the values of the people.
- Seek out and engage people from the community and beyond who can share cultural and scientific knowledge related to the community.
- Ensure that culture is foundational to the program.
- Use traditional ways of teaching and pedagogy.
- Create space for all knowledge and experience to be shared and respected.
- Approach things sacredly.
- Seek out creative collaborations to utilize resources within the tribe and community.
- Encourage policy change by modeling processes and educating stakeholders.
- Incorporate research on Native ways of knowing and Western science that is community initiated and overseen.” (pg. 67)

Although these practices have shown to be effective, they are designed to help communities start ISE programs tailored to fit the needs of unique, individual communities (Mack et al 2012).

Barnhardt and Kawagley (1998) show the impact of five initiatives on improving educational outcomes and increased interest in STEM, including: Native ways of knowing/teaching, culturally aligned curriculum, indigenous science knowledge base, elders and cultural camps, and village science applications. The following themes were present in all initiatives: documenting cultural scientific knowledge, indigenous teaching practices, standards for culturally-based curriculum, teacher support systems, and appropriate assessment practices.

Barajas-Lopez and Bang (2018) provide a salient example of using indigenous ways of knowing to transform an emerging field, making and maker spaces. By expand the idea of making and maker spaces through Indigenous ways of knowing Indigenous students are better supported to interact with and learn from the environment.



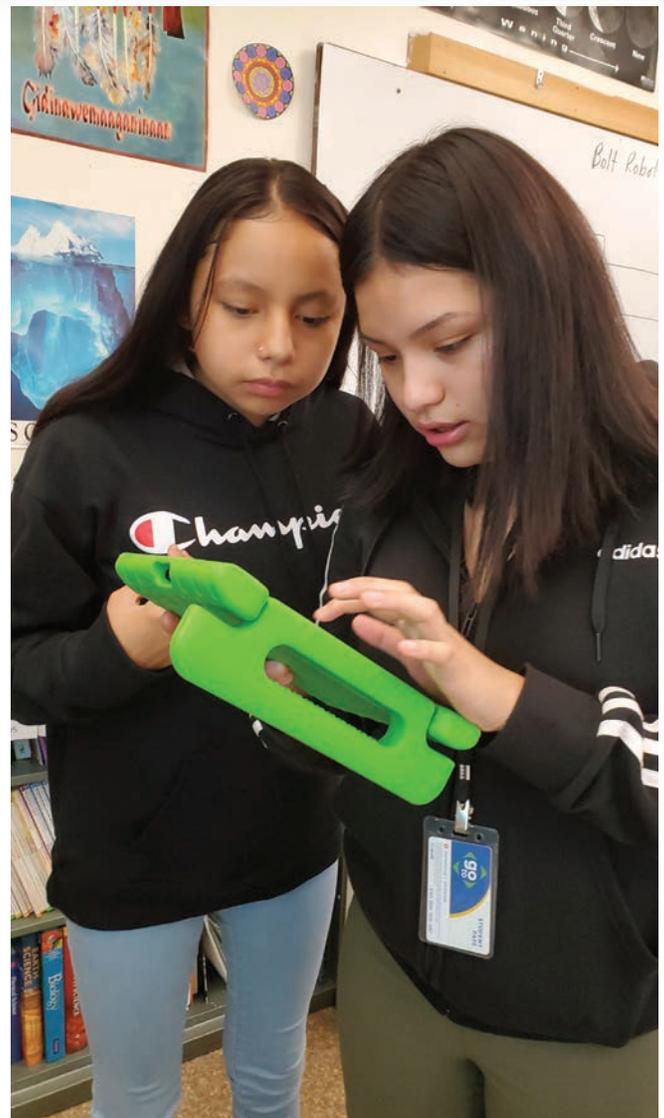
Within Indigenous knowledge is the idea of Indigenous or Native science. The body of literature exploring the meaning and impact of Native science is also continuing to grow. It should be noted that there is no one “Native Science” as different tribal Nations and individuals have different understandings. Further, science for Indigenous people is a way of life and science education is meant to ensure survival (Ollerenshaw and Lyons 2002). Kasun and Lopez (2017) define Native science as including Western science and expanding on it to include spiritual, emotional, physical, and mental aspects of human existence. They believe Native science should be incorporated into curricula with its benefits extending beyond Native student achievement to include healing the planet and affecting the trajectory of the practice of science. Iseke and Desmoulins (2015) identify seven tenets of Indigenous science: (1) experiential learning, (2) transformative learning, (3) cultural learning, (4) interconnectedness and learning within relationships, (5) apprenticeships with Elders, (6) recognize sacred teachings and respect knowledge, and (7) a relational approach, learning from Elders and other knowledge keepers.

Barnhardt and Kawagley 2005 assert Western scientists and educators must learn to understand Indigenous epistemologies rather than Indigenous students to learn Western science, carrying the burden of integrating their Indigenous science knowledge themselves. Furthermore, many articles explicitly called for Indigenous science to be included not as a token addition but a meaningful asset to curricula (Aikenhead 2002).

The above are serve as examples of culturally relevant curriculum integrating Native science into science instruction and its impact on Native learners. As part of state mandated culturally relevant curriculum, Native students in Montana score higher on standardized tests that include traditional knowledge (Dupuis and Abrams 2017). Dupuis and Abrams (2017) argue the science achievement gap for Native students, as measured by standardized test, could be reduced by changes in test construction, curriculum development, teacher support, and school funding. Curriculum should be changed to include traditional science knowledge and teachers should receive support to effectively teach culturally relevant curriculum (Dupuis and Abrams 2017).

Klump and McNeir 2005 provide case studies for the inclusion of hands-on curriculum rooted in Indigenous subsistence practices of local communities. Educators integrated traditional knowledge (i.e. berry picking) with academic standards (i.e. science, health, and personal/social skills) and saw positive results in enrollment rates, reduced crime in the community, stronger connection between students, teachers, and elders, and students reconnecting with their cultural heritage, as well as increased use of subsistence activities.

Within the literature of culturally relevant STEM education for Native students, incorporation of Indigenous knowledge and Indigenous science are ubiquitous; however, other themes arise including border crossing (Aikenhead 1997; Aikenhead 2002; Snively and Corsiglia 2001), place/land-based education (Chinn 2014; Reetz and Quackenbush 2016; Simpson 2014; Zwick and Miller 1996; Bang et al 2014), community-based education (Abrams et al 2013; Dalbotten et al 2014; Kasun and Lopez 2017), storytelling (Archibald 2008; Biin and Weston 2015; Marin and Bang 2015), and combination of these methods (Hugo et al 2013; Johnson et al 2014; Riggs 2015).



BORDER CROSSING

Aikenhead (2002) explored the impact of “culture” brokering with students and teachers in grades 6th through 11th, helping students cross the cultural border between their Aboriginal culture and the culture of Western science. Aikenhead (1997) suggests using cross-cultural science curricula, specifically science-technology-society (STS) curriculum to assist students in border crossing can improve their capabilities and motivations by drawing upon indigenous cultures.

Snively and Corsiglia (2001) explore the need for educators to help all science learners negotiate border crossings between Western modern science and Indigenous science through the context of Traditional Ecological Knowledge (TEK). TEK is a well-documented branch of Indigenous science that now has numerous examples of proven, ecologically relevant, and efficient Indigenous science. However, TEK and Indigenous science have often been displaced by Western modern science, deemed universal, with science educators serving as “gate keepers” who determine what can and cannot be included in science curriculum. Rather than aiming to exclude Indigenous science, educators should help all science learners to understand multiple ways of knowing and learning about the natural world.

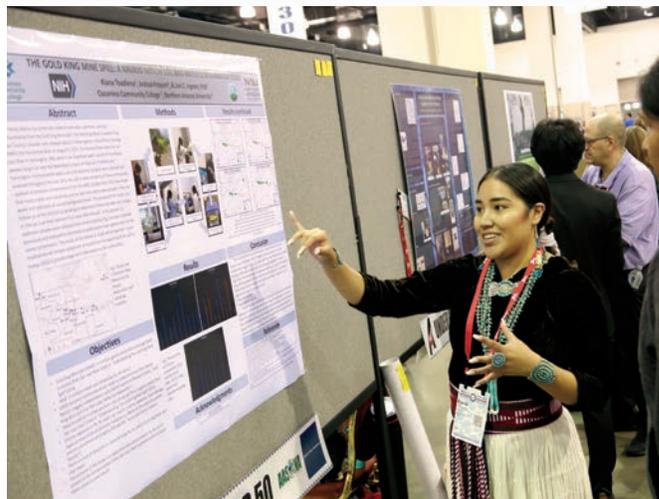


PLACE/LAND-BASED EDUCATION

Chinn (2014) recommended teacher professional development grounded in a Hawaiian cultural model of sustainability implemented through place-based lessons would connect formal and informal science knowledge and engage students in systems level thinking, problem solving, and civic action. A science-based archaeology program used place-based learning by using a traditional cultural learning environment to increase engagement and enthusiasm for archaeology, with community collaboration and partnerships contributing to the program’s success (Reetz and Quackenbush 2016). Simpson (2014) asserts “land as pedagogy” is critical for developing Indigenous people who have the skills, knowledge, and values to rebuild their Nations. Zwick and Miller (1996) found that American Indian students scored significantly higher on standardized tests when they received outdoor-based science education versus traditional classroom science methods; however, non-Indian students also scored higher when they had received outdoor instruction. When teachers and community members engage in land-based environmental science education that actively seeks to “restore(y)” Indigenous people as the original inhabitants, Indigenous youth and families learning experiences, agency, and resilience are significantly impacted (Bang et al 2014).

COMMUNITY-BASED EDUCATION

Abrams et al 2013 suggest community members contribute positively to the learning and understandings of Native youth and incorporating community into the teaching of science is more likely to engage students and families, leading to overall increased interest in science. Dalbotten et al 2014 used both community-based and place-based education to improve the learning opportunities available to Native students by developing community partnerships and using a culturally important plant as the focus of a science research camp. Kasun and Lopez (2017) review of Native Science in practice posits Native science education is most successful when community based (Goulet and Goulet 2015; Munroe et al 2013). They argue community engagement must be at all levels and should refrain from pan-Native content.



STORYTELLING - STORYWORK

Archibald 2008 frames indigenous oral narratives as an important source for Indigenous knowledge, intended as a tool for sharing Indigenous knowledge. Archibald coined the term “Indigenous Storywork” demonstrating how storytelling has the power to educate and build upon the seven principles of respect, responsibility, reciprocity, reverence, holism, interrelatedness, and synergy. Indigenous knowledge, teaching, and holistic learning practices were used to develop a storywork program that helped Aboriginal youth in Canada explore computer science (Biin and Weston 2015). Based on their work with American Indian teachers engaged in designing science curricula, Marin and Bang (2015) suggest American Indian teachers use storywork to build their science knowledge and design curricula aimed at sustaining and revitalizing indigenous cultures. Tzou et al (2019) found a family-based robotics workshop utilizing storytelling and centering Indigenous knowledge opened up new ways for students to engage in STEM while also learning to design new technologies. Using storywork allowed students to see computer programming and robotics as tools for creating, collaborating, and engaging in cultural practices.

COMBINATION OF METHODS

A geoscience education program for Alaska Native youth developed community partnerships and addressed community needs while holding Western science and traditional knowledge as equal and complementary epistemologies contributed to higher high school graduate rates and increased pursuit of college degrees (Hugo et al 2013). Johnson et al (2014) also integrated place, traditional tribal knowledge, and storytelling as part of Earth Science education on the Flathead Indian Reservation, leading to increased achievement in geosciences among Native students. Furthermore, this geoscience program collaborated with community members, elders, and cultural experts to develop curricular resources. According to Riggs (2015), Earth science curricula with explicit emphasis on outdoor education, place and problem-based structure, and inclusion of traditional indigenous knowledge are more successful for indigenous learners.





DISCUSSION & RECOMMENDATIONS

The literature paints a clear picture of the importance and value of Indigenous ways of knowing and Indigenous science in engaging Native students and learners in STEM. An emphasis on adapting to community contexts, engaging community in development, and connecting to community benefits are all important fixtures of culturally relevant STEM education. Place-based and land-based education strategies are also prominent in the literature as a means for increasing engagement in STEM, particularly in the fields of environmental science and geoscience. Finally, storywork serves as a compelling way to teach Indigenous knowledge as it is in and of itself an Indigenous way of knowing. Overall, the literature does support the notion that to improve the educational success of Native students and learners, STEM instruction must at least include, if not center, Indigenous ways of knowing and Indigenous science.

During the meeting of primarily Indigenous STEM education researchers, the group identified some key recommendations to complement the findings of the literature review. The group echoed the literature in calling for a welcoming of students' existing science knowledge and countering the notion there is a universal way of knowing. There was consensus around the importance of recognizing individual cultural knowledge and stating the value of that knowledge within the classroom. The group also supported the importance of community involvement, encouraging family to have a roll in learning, engage community in education and teaching, and develop a way for community to react and respond to STEM instruction. The group also discussed the importance of minimizing, facilitating, and making explicit crossing cultures and confronting epistemological differences rather than letting these differences go unsaid or unidentified. The group also brought up additional areas for supporting Native students in STEM, including connecting directly with students to create personalized learning and providing students who may not otherwise have connections diverse opportunities. The researchers also addressed the importance of addressing systemic inequity, looking at poverty and its effect on educational performance and changing the institutional value systems particularly as it relates to Native knowledge. The group also focused on supporting identity development, both Native and STEM identities, such that their multiple identities are not mutually exclusive, allowing students to see themselves as both Native and scientists. Similarly, the group sought to emphasize the many pathways of STEM, demystifying the narrow ideas of STEM career pathways, and helping students to see the relationships between their STEM interests and the applications and needs within their communities.

Some of the literature cited above and the AISES-hosted discussion of Indigenous STEM education researchers show the possibility for Indigenous science and Western science to work in concert rather than in conflict, with educational settings striving to support a multicultural lens rather than one of universalism and dominance. It is in this area that AISES can work to promote and support the meaningful inclusion of Indigenous science as equal to and essential in providing comprehensive STEM education. Furthermore, this asset-based approach, emphasizing the value and contributions of Native people, communities, and cultures, may be developed in the literature but in mainstream society and education systems this is not the case. Therefore, organizations like AISES and others who seek to promote Native people in STEM education and careers must work to center, uplift, and validate Indigenous knowledge and Indigenous science. AISES is in a unique position, interfacing with both educational systems, academia, industry, and philanthropy, to lead the way for innovative programming and curricula at a scale beyond that of typical research projects. Therefore, this literature review serves as a way for AISES to begin its capacity building efforts to integrate evidence-based approaches into its program development and implementation.



CONCLUSION

Indigenous people, cultures, and communities have rich histories, traditions, and ways of knowing, being, and connecting with the world around them. For too long mainstream education systems have undervalued and disregarded Indigenous Knowledge and Indigenous Science. Research now suggests these Indigenous assets are not only important for the success of Indigenous people themselves but for the healing and health of our world. Stemming from this foundation of immense wealth, researchers posit improved educational outcomes for Native and non-Native students result when STEM instruction is culturally relevant, rooted in Indigenous ways of knowing, linked to place, and embedded in community.

AISES seeks to learn from the literature, particularly that of Indigenous scholars, to improve the development and implementation of its K-12, STEM education programming. Incorporating the evidence-based strategies detailed in this literature review will position AISES to have an even more meaningful and impactful presence in the field of STEM education for Native students and learners.

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