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# A Review of Promising Practices in STEM Bridge Programs Serving High School and College Native American Indigenous Communities

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## Abstract

This paper presents a two-part systematic review conducted to uncover research-based major themes of importance according to indigenous education experts in Science, Technology, Engineering, and Mathematics (STEM) education. The second part of the study is a review of select case studies that highlight a set of promising exemplary practices effective in designing and implementing STEM bridge programs to serve middle, high school, and college indigenous students. A historical review of related STEM program partnerships between the National Aeronautics and Space Administration (NASA) and some Tribal Colleges and Universities is presented to highlight past approaches and to support some of the presented recommendations. This review may be particularly relevant to government agencies and business groups who wish to collaborate with universities to support the development of career pathway preparation programs for underrepresented students in STEM.

### Introduction

A systematic review is similar to a literature review, but can, in and of itself, be considered a proper educational research methodology [1]. The systematic review is considered a form of secondary research that examines existing research using specific research methods. In this paper, the intent is to investigate the impact of various interventions (STEM educational bridge programs) using a conceptual framework that is connected to "indigenous ways of knowing", a term that will be defined in the next section. The focus will be on a particular group of people (American Indian/ Alaskan Native (AI/AN)) and the examination is on the broad possible outcomes of the intervention. This follows a broadly aggregative synthesis logic.

This study is a systematic review of promising research-based themes and operational approaches of effective Science, Technology, Engineering, and Mathematics (STEM) bridge programs that serve American Indian or Alaska Native, students. According to the U.S. Census Bureau, American Indian or Alaska Native refers to a person having origins in any of the original peoples of North and South America who maintain tribal affiliation or community attachment. A bridge program is defined as any organized enrichment effort that supports groups of students to

succeed during key academic transition periods such as from middle grades to high school or high school to college/university. Often, the analysis of issues in STEM education disparities focuses on other underrepresented groups in STEM careers such as women, Hispanics, and African Americans. These are important efforts and due to representation, an important demographic to consider. However, we cannot assume that issues that have been found to be critical for the success of women, African Americans, Hispanics, or other underrepresented minorities in engineering programs at US institutions of higher education, will also be effective for American Indians/ Alaskan Natives  As will be presented, there are fundamental, complex, vast and varied aspects of Indigenous Ways of Knowing [2] that originate from cultural experiences and this demands a separate and respectful study. A special focus on efforts carried out by tribal colleges and universities is important given the continuing underrepresentation of American Indian and Alaskan Natives in STEM careers and given the differences in culture and theoretical intent to broaden student participation in STEM programs and careers.

## Background

### Underrepresentation of American Indian and Alaska Natives in STEM

Although American Indian/Alaska Natives make up 1.2% of the total population, according to the National Center for Science and Engineering Statistics, AI/AN students are underrepresented in science and engineering at the bachelor's, master's, and doctoral levels. There are only 3 out of 1,000 (0.3%) AI/AN students in the US Engineering workforce, and only 1 out of 13,000 AI/AN women are represented in the US Engineering workforce. In addition, the number of American Indian or Alaska Native doctorate recipients has remained constantly low (under 1%), only changing from 117 doctorate degree recipients in 2010 to 120 in 2019 [3].

### NASA Historical Efforts with Tribal Colleges and Universities

According to Maynard [3], NASA has supported an effort called "Tribal Colleges and Universities Project (TCUP)" since 2010, as one of various STEM education and outreach grant programs specifically targeted to support Tribal Colleges and Universities-related initiatives. "The overall goal of the project is to expand opportunities for the nation's STEM workforce through capacity building, infrastructure development, research and engineering experience, outreach, and information exchange" [4]. In 2008, Congress directed NASA to establish a project that was focused on climate change education. The Global Climate Change Education (GCCE) project announced its first solicitation and twenty-two projects were selected for funding. In 2012, the project was renamed Innovations in Climate Education. In 2013, NASA announced a new solicitation under the Minority University Research and Education Project ... (MUREP) umbrella, with a particular solicitation directed to tribal institutions. In 2014, the project was renamed Earth Systems, Technology, and Energy Education for MUREP (ESTEEM) to convey the broader scope of the educational resources being developed, as the study of climate encompasses the study of Earth systems and energy. That year, ESTEEM awardees: Northwest Indian College, Salish Kootenai College, and Fond du Lac Tribal and Community College. In 2018, ESTEEM merged with the larger agency-wide Initiative within MUREP for American Indian and Alaska Native STEM Engagement, MAIANSE.

### MUREP for American Indian and Alaska Native STEM Engagement, MAIANSE

MAIANSE is the acronym for the Minority University Research and Education Project (MUREP) for American Indian and Alaska Native Science, Technology, Engineering, and Math (STEM) Engagement. This NASA program works to engage American Indian and Alaska Native students and institutions in authentic and unique experiences. Various funded efforts comprise this initiative. Student engagement through internships, competitions, and networking at student national conferences such as the American Indian Higher Education Consortium (AIHEC) Conference, the American Indian Science and Engineering Society (AISES) Conference, and the Society for the Advancement of Chicanos/Hispanics and Native Americans in Science (SACNAS) Conference. Additionally, MAINSE aims to build capacity at Tribal Colleges and Universities (TCUs) and American Indian and Alaska Native Serving Institutions (AIANSIs) by awarding competitive cooperative agreement funding to support TCU comprehensive efforts, linking awardee institutions and their students, faculty, and staff to STEM experiences by developing unique curriculum and providing professional development for educators.

## RESEARCH METHODOLOGY

### Research Questions

Two overriding research questions guiding this systematic review are as follows: 1) What major philosophical premises regarding science education and indigenous ways of knowing science have emerged as influential for improved and focused STEM intervention design for American Indians/ Alaska Natives? 2). What major themes or practices are highlighted in select case studies as integral to the design and implementation of successful bridge programs to best serve indigenous students in the United States?

### Methodology

A semi-systematic, integrative review approach was used to identify major themes and promising practices in more than fifty primary research and practitioner-published articles and reports to support the investigation of the stated research questions. In this case, the intent of the review was not to cover all articles published on the topic, but rather to combine perspectives to create guiding principles for new theoretical models and implementation recommendations. The search key phrases used to identify the fifty articles were: “STEM bridge programs for indigenous students” and “indigenous or native or aboriginal or Indians or first nations”. Through this method, themes were identified, analyzed, and reported here. In addition, seven specific programs were selected as case studies that demonstrate some of these themes and practices in successful operationalized program models.

The articles were selected from the following four journals:

1) Journal of American Indian Education
2) ASEE conference proceedings
3) New Directions for Higher Education
4) Cultural Studies of Science Education

## THEMATIC FINDINGS

**Teach STEM Content in Context and with Cultural Relevance**

In a recent study [5], the authors used the Indigenous research guiding principles of Respect, Relevance, Reciprocity, Relationship, and Responsibility [6] to carry out a research study using an asset-based research approach. In this study, they reviewed data from the National Assessment of Educational Progress (NAEP) to identify mathematics questions in which AI/AN students outperformed their non-AI/AN peers. The questions were analyzed. AI/AN students were found to perform better on questions with the following themes: a) questions with the use of a diagram; b) questions related to everyday contexts familiar to students; c) questions involving geometric/measurement problems related to cultural work including shapes and patterns; d) questions involving transformations and e) questions related to the cultural situation related to AI/AN experience. This work demonstrated to the authors the importance of both employing a respectful approach to research and the impact of a culturally-relevant curriculum to truly understand the assets of students.

Demmert and Towner's review [7] pointed to a new curriculum, "Math in a Cultural Context" (MCC), developed by Lipka and Adams [8] truly highlights the case that culture matters- even when teaching mathematics. The MCC curriculum integrated elders' knowledge of the particular design of unique artifacts. These artifacts are then integrated into mathematical problem-solving situations that connect that knowledge to the teaching of mathematics concepts. The authors believe the power of these cases resides in the long-term collaborative work between insiders and outsiders, resulting in an effective culturally-based curriculum. These studies demonstrate that MCC's math curriculum makes a difference in the math performance of AI/AN students and the data shows that consistent instruction using math instruction with cultural contexts can also potentially close academic performance gaps.

**Acknowledge the Indigenous Worldview**

Our conception of the world- our worldview- is generally defined by our philosophy of life. This is generally culturally and experientially based. Traditional Western worldviews tend to be aligned with scientific logic, requiring proof and consideration of separate, compartmentalized knowledge bins to try to understand a bigger concept. On the other hand, an Indigenous worldview usually contains a comprehensive or holistic approach to understanding the whole. It is also spiritually oriented, and interconnected, and allows for a non-linear and cyclical phenomenon. And Indigenous Knowledge Systems (IKS) refers to the worldview as well as the skills and knowledge developed by Indigenous societies.

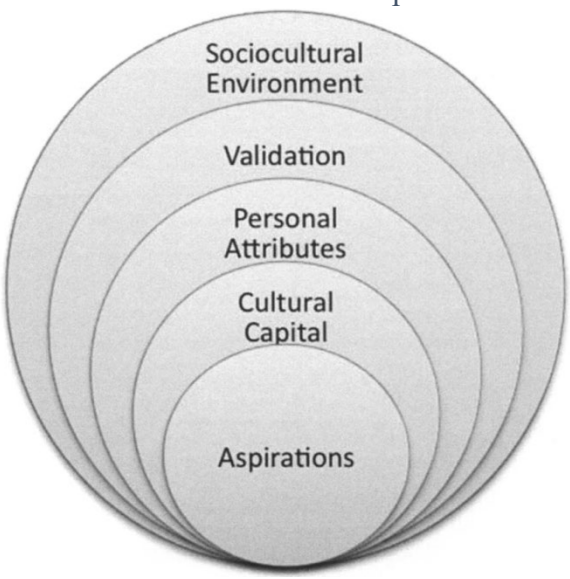
Robertson and Etherington [9] used an Indigenous worldview as a lens to understand approaches to develop students into individuals with deeper empathy and understanding. They advise the need to take a posture of humble learning to create relationships with Indigenous peoples. "Benevolence can be experienced by Indigenous people as relationally oppressive", it is essential that one seek the perspective of the recipient" (9, p.101). In this qualitative study, interviews revealed that an understanding of native people, their culture, and their historical background is crucial and that respect is not shown only through words but also actions. What sets benevolence apart from humble action is the foundation of a relationship. It is all about having a relationship first.

Andrade, M. S. [10] discusses the importance and relevance of TribalCrit (Tribal critical race theory, as proposed by Brayboy [11]. TribalCrit highlights the importance of understanding the

interactions between American Indian students and institutions of higher education to facilitate cultural pride and the integration of both Indigenous and Western ways of knowing. It is particularly critical to understand the broader context of colonization and its effect on American Indians. Thus, Andrade [10] discusses the importance of engaging respectfully and acknowledging the Indigenous worldview and ways of knowing. This study focuses on factors reported by American Indian women as those that have led to their success in higher education. Their findings inform the development of a model or framework that organizes factors that influence success in educational aspirations (shown in Figure 1 below).

This model highlights sociocultural experiences and validating experiences as critical to a positive higher experience for American Indian women.

Figure 1. Framework for Educational Aspirations




The themes presented in the findings of their study were based on n=18 returned surveys with multiple choice and open-ended questions related to 1) Honoring Family, 2) Social Models, 3) Encouragement and Support, 4) Values and Attributes, 5) Service, 6) Learning, 7) Hard Work and 8) Self-efficacy. They highlight the interconnectedness of individual women's lives and conclude that the interviewed women's voices confirm that education and knowledge can provide the means to help family and community.

**Engage in Community-based Participatory Research & Respect the Family Framework**

Lane and George [12] discuss the need for a community-based participatory research approach to support culturally competent, empowering research. The following themes were identified through the researchers' interpretation of the data and validated through their research methodology:

1. Positive family influence impacted high school students' motivation to graduate from high school.
2. Student self-awareness motivated them to succeed in graduating from high school.
3. Coaches, teachers, and school staff had a positive influence on students' ability to graduate. Further, teachers who took the time to teach about the contributions of Native Americans were appreciated by students for their demonstration of respect and appreciation.
4. Friends proved to be one of the most positive peer relationships offering mutual support.

When working with students, it is necessary to help students develop meaningful goals with clear paths towards achievement, often relying on leveraging family support, using a Family Education Model developed by Heavyrunner & DeCelles [13], Ortiz and Heavy Runner [14] developed a family education model that is very relevant to this review.

**Leverage Indigenous Knowledge Systems and Facilitate Transculturation Processes**

Johnson et al. [15] developed a framework to improve the recruitment and retention of STEM students. In developing their model, they considered transculturation [16], socialization, and indigenous knowledge systems to highlight the promising practices. They are based on the inclusion of the following five notions:

1. Important role of family involvement
2. Role models and mentors
3. Financial support and communications
4. Community cultural wealth
5. Cultural community and social activities

This study was conducted with AI/AN students with the realization that they are often represented as a monolithic group. AI/AN people belong to the 567 federally recognized tribes in 36 states in addition to those still seeking recognition. Although in general, AI/AN students share a collectivist culture, there is often conflicting self-reliance and distrust in non-tribal organizations that impede students from seeking help in college. The study presented a movement from a deficit perspective to a capacity-building perspective of AI/AN persistence in STEM.

1) The transculturation premise allows students to use their ethnic identity as an emotional anchor. The question is how to engage in the STEM/institutional culture without having to assimilate.
2) There is a transculturation threshold that is an important marker. It is a point at which students make conscious decisions as to the balance between ethnic pride and professional selves.
3) Students can successfully engage in two cultural settings without assimilation.
4) Cultural learning occurs as a process of socialization. When students retain a strong connection to their culture of origin, it increases their success.

The theoretical basis of Indigenous Knowledge Systems (IKS) was used as a guiding framework for this research. This term refers to respect for traditional Indigenous science and ecological points of view as well as careful regard toward place-based cultures, worldviews, ways of knowing, and respect for past generations. An example of this concept, enacted, is to focus on processes. In most indigenous languages, words such as education, science, or art do not exist, rather the emphasis is upon the processes or journeys in the "coming-to-know", or "coming-to-understand" [17]. See Table 1 below for the elements and examples suggested for individuals and institutions as part of this framework:

Table 1
Faculty Practices and Institutional Practices Based on IKS (modified from Johnson et al. [18])

| | Sample Advisor/Faculty Practices | Sample Institutional Practices |
|---|---|---|
| Family Involvement | Become aware and accept the central role family and Tribal Nations play in students' lives. | Welcome and learn from TCU practices and other institutions of higher education to share knowledge and develop programming that enhances family presence. |

| | | |
|---|---|---|
| Role Models and Research Mentors | Train mentors to be culturally responsive; Help students navigate the norms and values found within the STEM majors. | Employ peer mentoring directed by faculty for graduate students to mentor undergraduate students in STEM. |
| Financial Support and Communication | Discuss early and often, time to degree limitations and financial support. Provide direction to dedicated financial support staff. | Communicate with alumni foundations to campaign for endowed scholarships and recognize supported students publicly. |
| Community Cultural Wealth Building | Have faculty introduce students to scholarly activities and professional networks. | Designate a dedicated administrator/dean as a student advocate and connection to psychosocial support. |
| Cultural Community and Social Activities | Hire AI/AN faculty/staff and bring visiting scholars to the institution across disciplines as researchers. | Dedicate a centralized space or gathering to support student research and skill-building opportunities. |

The experiences of Dine (Navajo) students in various summer residential programs for gifted Indigenous students are described in a study by Wu and Gentry [5]. They comment on the consistent underrepresentation in the number of students (Indigenous, Hispanic, and African American), who are identified for participation in gifted programs. As background information, they discuss a few summer programs for Native American students: 1) The Native American Intertribal University Preparatory Summer Program [19]; 2) The Project Leadership Excellence Achievement and Performance program [20]; 3) the Ohiyes Program, and 4) the Minnesota Indigenous Youth Freedom Project. Finally, they outline the GERI summer residential program at Purdue and their postpositivist approach as researchers in conducting research among people and learning with them at the same time. The five major components of the GERI programs led to positive social interactions, the student defines life-changing experiences, and increases in motivation related to positive academic experiences and student success.

**Support Personal Tribal Values of Self-Empowerment and Interact Purposefully with the Comprehensive Understanding of Home and Place**

Joseph and Windchief [18] present not only a thorough explanation of personal tribal values relevant to student perseverance in STEM academic studies but a comprehensive model that connects both values and self-empowerment through learning and interacting with each learner's environment. *Nami'nangwa* is a Hopi value of helping one another; it is holistic, spiritually shared, and involves reciprocal energy. The work presented and the spirit of the contribution is done with the motivation of *Nami'nangwa*. So, it is with this foundation that the *Nahongvita* model was developed. The process of self-empowerment is crucial to learning. Self-empowerment is about exerting oneself and making an effort. This effort is then manifested as one's inner strength,

The *Nahongvita* model (Figure 2) highlights the natural intersection and roles of home environments, academic environments, and community, all with an acknowledgment of Indigenous history and the specific aim of empowering AI students from rural communities to succeed. Tribal communities share in experiences of forced colonial schooling, assimilation, and removal from their traditional homeland. This traumatic collective experience can be recalled

and leveraged to make stronger connections to the community that in turn will enable sought-after self-empowerment.

Figure 2. The Joseph and Windchief Nahongvita Model [18]


The next section will summarize the highlights of seven selected case studies. These were selected since they involved AI/NA participants, were carried out in the United States in the last 30 years, and included bridge programs as intervention programs for STEM students transitioning from middle school to high school or high school to college.

## CASE STUDY HIGHLIGHTS

### Case#1-Alaska Native Science and Engineering Program (ANSEP)

The program design and focus of ANSEP is meant to effect systemic change in the hiring patterns of Alaska Natives in science and engineering. The ANSEP programming elements include a Middle School Academy, a high school, and a Summer Bridge Program. It is a longitudinal education model that provides a continuous string of components beginning with students in sixth grade, continuing through high school, into science and engineering undergraduate degree programs, and through graduate school to the Ph.D. The program supports students from 95 communities, providing them with inspiration, guidance, and opportunity around STEM careers. This model has been in development after 18 years of effort and with the awareness that a fragmented approach that focuses on one academic level is not adequate to deal with the scope of the problem. Each component is based on the fundamental Native principle of working together in a community.

According to Shroeder and Lassel [21], a longitudinal study that followed participating middle school students through college showed that the ANSEP Middle School Academy students

complete Algebra 1 by the end of 8th grade at a rate of 83% as compared to the national average of 26%. More than 50% of ANSEP high school students graduate engineering ready compared to 4% of minority students nationwide. 96% of the ANSEP Summer Bridge students successfully transition to BS STEM degree majors and more than 70% of them graduate.

Studies also recorded the opinions of the students, noting that they experienced statistically significant increases in perceived levels of academic and social engagement, peer support, congruence with the university, and commitment to complete their degrees. An additional study conducted by Yatchmeneff [22], used the self-determination theory of motivation to examine autonomy, competence, and relatedness. Analyzing the results of thirty-three student interviews, she found that ANSEP, directly and indirectly, motivated its participants to take more advanced math and science courses in high school and fostered an intrinsic motivating environment.

**Case#2- STEM Education Pathways in the North Dakota Reservations**

This case study described the collaboration between tribal high schools, five tribal colleges in North Dakota, mainstream universities, and engineering profession stakeholders. In this case, according to Padmanabhan, Pieri, and Davis [23], the programs were designed to not only motivate but also to guide and nurture through graduation. The program included components such as Sunday Academy, High School Summer camps, research experiences, and scholarships for Tribal College students and faculty. Engineering professional stakeholders contributed as speakers, subject matter experts, mentors, and also as participants learning about culturally responsive approaches and asset-based practices. The noted outcomes were that a majority of participating students declared the associate of science as a major, graduated with STEM bachelor's degrees, and students attended STEM professional conferences and presented their research STEM topics at conferences.

**Case#3- North Arizona University STEP Up program for High School Girls.**

This program was designed as a STEM engagement program that considered the importance of multi-contextuality as a tool in the use of effective pedagogy with a focus on Native American women. According to Swimmer and Jarratt-Ziemski [24], some of the top issues contributing to the decision to switch out of STEM majors for female and male students are psycho-social in nature. Research shows that, while women may be academically and intellectually capable, they may lack confidence in their science and engineering abilities. Therefore, early support for the development of these skills is critical. According to Ibarra [25], " … those who are multi-contextual, learn better in a place where multiple ways of knowing are embraced". Pre-college outreach programs, particularly residential STEM camps for Native American females, can be particularly effective.

**Case#4- Research Center-Based Mentoring Program**

This is a presentation on the use of research center-based mentoring to increase minority participation in engineering. The authors outline some of the theoretical research bases of mentoring such as Gershenfeld, [26], Nora and Crisp [27] and Tinto [28]. They posit that minoritized students face discrepancies in mentoring opportunities and those students in academic engineering departments encounter additional difficulties, given the strain upon faculty in their traditional roles. Researchers work with 15 students each year, managing formal and informal mentoring relationships as part of a model of networked mentoring that includes

individual-to-researcher, individual-to-team, friend-to-friend, and peer-to-group. Over a 4-year longitudinal study with only minority students, researchers find that, as compared to the control group, participating students had a higher average cumulative GPA and short-term gains in retention. However, more and deeper reasons for long-term losses in retention indicate the need to focus on more than just mentoring as support for minority students in STEM.

**Case#5- Indigenous Mentoring Program**

Brown and Komlos [29] created an Indigenous mentoring program to support Indigenous scholars' contributions to STEM fields with a focus on protecting their Indigenous identities and internal scientific methodologies. The Indigenous Mentoring Program (IMP) was designed to educate primarily non-American Indian faculty to become attuned to the unique individual and community needs of their American Indian and Alaska Native students, while simultaneously providing access to the students for graduate study in the STEM fields [30].

The IMP offered faculty mentors an opportunity to identify and reject the accepted deficit-model discourse surrounding American Indian and Alaska Native students and, instead, seek an alternative that is respectful of native ways of knowing and, in addition, presenting information in a way that is relevant to students' lives. A new focus on traditional support systems has been found to have positive impacts on American Indian and Alaska Native students' academic experiences Specifically, the psycho-social support resulting from a mentor relationship was found to increase students' satisfaction with their entire academic experience. In their study on the AI/AN undergraduate experience in STEM, Smith, et. al. [31] suggest that AI/AN students with a strong sense of belonging and assurance in their tribal identity face challenges in finding a sense of belonging in STEM fields. Their review of the literature for conceptualizing a mentoring program for AI/AN graduate students found varying mentoring formats for historically URMs that are place-based, considerate of mentor positionality, influenced by institutional setting, and attentive to student identity location.

They aimed to develop and implement an Indigenous Mentoring Program that considered the STEM fields, the graduate levels of study (master's and doctoral), and the North American Indigenous context.

Specific approaches discussed:

1. The Indigenous Mentoring Program included monthly sessions with content presenters,
2. Self-locations statements asked students to describe their family of origin, academic role, and research area.
3. Professional Development (PD) information was shared with faculty using various resources regarding general student support information as well as indigenous mentoring models, research methodologies, cultural humility, and ceremonial and cultural events.

**Case#6- The Pacific Northwest Circle of Success Mentoring Opportunities in STEM (PNW-COSMOS)**

Windchief [32] concludes that most graduate STEM programs in the United States are lacking in their efforts to recruit and retain AI/AN students. He points out that the low representation of AI/AN faculty in STEM is one attributable cause and directly leads to mentoring without

representation. Windchief also discusses the importance of considering Indigenous community-informed practices to empower faculty to recognize the multiplicity of AI/AN students in their identity formation.

**Case#7- Indigenous Model for Understanding**

Kayongo-Male's [33], model for understanding State University-Tribal college collaboration. Indicators of successful collaboration were derived from the W. K. Kellogg Foundation's 1999 President's Commission report [34] on the engaged institution that called for land grant institutions to reach out more authentically to underserved communities. These indicators include respect for partners, resource partnerships, responsiveness, accessibility, integration, academic neutrality, and coordination.

## DISCUSSION

Many organizations, educational, corporate, community, and governmental, define goals to address workforce development, especially where there may be gaps in broader demographic representation. However, systematically reviewed literature is not often easily available, especially that which focuses on specific practices and cases involving populations not often featured, such as American Indians and Native Americans. In addition, through the work presented here, many Indigenous authors and researchers are highlighted and Indigenous Knowledge Systems are presented. The recurring themes from the review of these articles are discussed below.

One important theme that is prevalent in this review is the recommendation that STEM content is most effectively conveyed when it is taught in context and with cultural relevance. To accomplish this well, the people involved in instruction planning and teaching must take the time and care to listen to the students and attempt to understand their experiences, their community priorities, and particularly, their deeper world views.

The writers reveal through these various cases the importance of acknowledging the Indigenous Worldview. A comprehensive study of the Indigenous worldview is important as many factors within the Western worldview of STEM are quite different from the Indigenous worldview. STEM content is to be presented thoughtfully and in a manner that respectfully leverages key Native ways of understanding Science and Engineering. Instructors may leverage Indigenous Knowledge Systems and facilitate transculturation processes by utilizing existing frameworks and models for IKS and transculturation.

Another recommendation is to offer support for students throughout their full learning trajectory, from kindergarten through graduate school. It is appropriate to support efforts that focus on very young students as well as students further in their learning journeys. This support should also be extended to instructors. Efforts should be exerted into offering extended training to instructors and facilitators in STEM education pedagogies that broadly support all students to feel motivated and valued. These approaches have the additional benefit of contributing toward students developing a positive identity as STEM learners. By utilizing existing frameworks and models for Indigenous self-empowerment, participants interact purposefully with the comprehensive understanding of home and place.

This review also encourages program-change participants engage in community-based participatory research, respect the family framework and incorporate a network of partners who understand their communities of students and their needs. These partners might include community leaders, educators, corporate and government partners, and other non-profit organizations.

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