

TRADITIONAL ECOLOGICAL KNOWLEDGE OF STEM CONCEPTS IN INFORMAL
AND PLACE-BASED WESTERN EDUCATIONAL SYSTEMS:
LESSONS FROM THE NORTH SLOPE, ALASKA

By

Linda Nicholas-Figueroa, B.S., M.A.

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Approved:

Lawrence K. Duffy, Committee Chair

Ray Barnhardt, Committee Member

Kriya Dunlap, Committee Member

Cathy Middlecamp, Committee Member

Tom Green, Chair

Department of Chemistry and Biochemistry

Paul Layer, Dean

College of Natural Science and Mathematics

Michael Castellini, *Dean of the Graduate School*

Abstract

Upon regaining the right to direct education at the local level, the North Slope Borough (NSB) of Alaska incorporated Iñupiat educational philosophies into the educational system. The NSB in partnership with the University of Alaska Fairbanks established Iḷisaḡvik College, the only tribal college in Alaska. Iḷisaḡvik College seeks to broaden science, technology, engineering, and mathematical education on the North Slope. Incorporation of place-based and informal lessons with traditional ecological knowledge engages students in education. Iḷisaḡvik hosted a 2-week climate change program from 2012 – 2015 for high school and middle school students that examined climate science and the effects of a warming climate on the local environment from a multitude of perspectives from scientists, Iñupiat Elders, and instructor-led field trips. Pre-assessments and post-assessments using the Student Assessment of Learning Gains tool measured students' interests and conceptual understanding. Students developed and enhanced their understanding of science concepts and, at the end of the program, could articulate the impact of climatic changes on their local environment. Similarly, methods to incorporate Indigenous knowledge into research practices have been achieved, such as incorporating field trips and discussion with Elders on the importance of animal migration, whale feeding patterns, and the significance of sea-ice conditions, which are important community concerns.

Dedication

To my daughters,

Janelle Nicole Nicholas &

Angela Shari Nicholas

I am truly grateful for their effortless continued
support throughout the many years of my journey

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General Introduction

Education in rural regions located above the Arctic Circle of Alaska (today known as the North Slope Borough) transitioned from family oriented Indigenous lifestyles to Western educational systems with the onset of Westernization beginning at first with missionary boarding schools (Nicholas-Figueroa et al., 2015) then with the organization of the North Slope Borough and the evolution of the Alaska education system in 1959. Western educational systems imposed strict methodical lessons that had little relevance to the education the youth required to support their subsistence way of living and surviving in harsh environments of the Arctic (Dinero, 2004). In the early years of the enactment of Western education, students were sent to boarding schools. Much of their culture, including speaking their own language, was stripped from them as a means to expedite acculturation and the learning of Western ways, which were deemed by Westerners to be superior to the ways of Indigenous peoples (Nicholas-Figueroa et al., 2015). Many of these students struggled with these changes, others straddled the fence, and some of them managed this transition, which in the end, provided the means needed to eventually negotiate the federal courts to retain their lands and much of their subsistence ways of life.

Today there are still many students who struggle with maintaining their cultural identities as more Western ways are introduced into their communities from processed foods shipped in to their local stores, which replace important Native dietary foods (marine meats, seafood, caribou, and berries (Barnhardt & Kawagley, 2010), to snow machines, which replace the use of dog teams. Both of these ways reduce physical activities that are necessary in maintaining their health.

Western education, undoubtedly, is here to stay. However, it is just as important for students to learn their culture and history to help them obtain the necessary skills to survive in the forever changing Arctic environment, while at the same time, fulfill their needs to be part of a culture that has survived for over 10,000 years. The Iñupiat, the people residing in the Arctic, are committed to assuring that their culture, especially their language, is not lost within the Western educational systems.

Through Federal regulations and court decisions imposed on the Alaskan school system, school facilities were built in the Native villages, allowing students a choice to stay with their families (Nicholas-Figueroa et al., 2015). Eventually, the Iñupiat peoples gained some control of the educational processes for their youth (Barnhardt & Harrison, 1993). This was accomplished by Eben Hopson, the first governor of the North Slope Borough in 1975. Later in 1986, the first college, Iḷisaḡvik College (formally known as Arctic Sivunmun Iḷisaḡvik College), was formed in Barrow, Alaska, (largest village of the North Slope Borough). In 2006, this school was officially recognized by the Federal government as a tribal college, the only tribal college in the State of Alaska. Iḷisaḡvik College is committed to incorporating the Iñupiat culture and values into their academic curriculum, to include the fields of science, technology, engineering, and mathematics (STEM) (Nicholas-Figueroa et al., 2015).

Place-based education combined with traditional ecological knowledge is a means to engage students in STEM curricula and important practical applications to the learning process can be addressed through current issues relevant to a student's home environment. One important issue is that climate change is having an increasing impact on the North Slope of Alaska. Over the last 60 years Alaska has experienced a 6° Fahrenheit (F) increase in winter temperatures and a 3 °F increase overall, twice that of the rest of the planet (EPA, 2015) giving

reasons for Iñupiat concerns that global warming may have significant impacts on the local environment and waters. For example, Arctic wetlands are the most productive systems in the Arctic tundra, responsible of the highest carbon exchange with the atmosphere and summer home of millions of migratory birds (Nicholas-Figueroa et al., 2016). Biological, hydrological, and chemical changes of these Arctic wetlands have suffered over the past half century due to a warming climate (Nicholas-Figueroa et al., 2016). In addition, concerns related to changing conditions in sea-ice and permafrost, plant coverage, animal migration, and beach erosion are relevant to subsistence living (Nicholas-Figueroa et al., 2016).

To engage students in the understanding of climate science and STEM concepts, a STEM summer science program offered by Iñisagvik College, the University of Alaska Fairbanks, and supporting partners, *Climate and Permafrost Changes on the North Slope in Cultural Context*, was developed. This program consisted of science modules with a central focus on the carbon cycle and the physical impacts of a warming climate. The cooperative format included assignments, communications with Iñupiat Elders and scientists, and instructor-led field trips. Elders shared traditional ecological knowledge associated with subsistence and the environment. Scientists provided hands-on laboratory experiences along with practical field work. Field trips linked practical applications communicated by the Elders and scientists. The Student Assessment of Learning Gains (SALG) (Seymour et al., 2000; SALG, 2013) determined students understanding of science concepts and how a warming climate impacts their local environment. Based on SALG pre-assessments and post-assessments of lectures, discussions, and field trips, students reported increased learning in areas such as “the burning of methane,” “what are biogeochemical cycles,” and “how these topics can relate to their village (Nicholas-Figueroa et al., 2016).”

Informal, place-based, and teaching through traditional or Indigenous knowledge is gaining further recognition in higher educational institutions. Information relayed to students comes in the forms of including Native language (Riggs, 2004) and art (Palmer et al., 2009) into curricula and incorporating Indigenous knowledge into place-based activities. The new concept of incorporating Indigenous knowledge with research projects presented at science fairs is demonstrated to add practical value to the Indigenous student. Scientific research is yet another venue to incorporate Indigenous knowledge. For example, research is widespread in the communities on the North Slope of Alaska. Research conducted on the North Slope include learning the importance of animal migration, whale feeding patterns, and the significance of changing sea-ice conditions, which are important community issues. Student exposure to these activities using place-based settings, Elders' Indigenous knowledge and the students' own observations can add great significance to the students understanding of STEM concepts.

References

- Barnhardt, R. and Harrison, B. (1993). Developing Tribal Education Strategies in Indigenous Communities. In *Discourse: the Australian Journal of Educational Studies*. Retrieved from <http://ankn.uaf.edu/Curriculum/Articles/TribalEducationStrategies.html>
- Barnhardt, R. and Kawagley, O. A. (2010). *Alaska Native Education Views From Within*: Alaska Native Knowledge Network, Center for Cross-cultural Studies, University of Alaska Fairbanks.
- Dinero, S. (2004). The Politics of education provision in rural Native Alaska: the case of Yukon Village. *Race Ethnicity and Education*, 7(4), 401-419.
<http://dx.doi.org/10.1080/1361332042000303405>
- EPA (2015) Environmental Protection Agency: Climate Impacts in Alaska., <http://www3.epa.gov/climatechange.html>. Accessed October 26, 2015
- Nicholas-Figueroa, L. Barnhardt, R. Duffy, K. Dunlap, K. van Muelken, M. and Middlecamp, C. (2015). Delivering Post-Secondary STEM Education on the North Slope, Alaska: Resilience and Adaption. *International Research in Education*. 3(2), 80-92. doi: 10.5296/ire.v3i2.7555
- Nicholas-Figueroa, L. Hare, R. van Muelken, M. Duffy, L. and Middlecamp, C. (2016). Iḷisaḡvik Tribal College summer climate program: teaching STEM concepts to North Slope Alaska high-school and middle-school students. *Journal of Environmental Studies and Science*. p. 1-10. Retrieved from <http://link.springer.com/article/10.1007/s13412-016-0413-6>.
- Palmer, H. Douglas, E. Watson, M. Kloesel, K. and Palmer, K. (2009). Xoa:dau to Maunkau: Integrating Indigenous Knowledge into an Undergraduate Earth Systems Science Course. *Journal of Geoscience Education*. 57(2): 137-144
- Riggs, E.M. (2004) "Fostering Indigenous Earth Science: Increasing Native American Participation in the Earth Science Enterprise" invited abstract for the 2004 Fall meeting of the American Geophysical Union, special session on "Diversity and Equity in the Earth and Space Sciences: 1. Global Perspectives on the Issues and Obstacles"
- SALG (2013) Student Assessment of Learning Gains, <http://www.salgsite.org/instructor/signin>; <http://www.salgsite.org>. Accessed December 22, 2015
- Seymour E, Weise D, Hunter A, Daffinrud SM (2000) Creating a better mousetrap: on-line assessment of their learning gains., National Meeting of the American Chemical Society, <http://www.salgsite.org>. Accessed December 23, 2015

Chapter 1

Delivering Post-Secondary STEM Education on the North Slope, Alaska: Resilience and Adaptation¹

Abstract

Prior to the 1960s, the majority of rural students seeking an education moved from their village to regional population hubs to attend boarding schools. Based on Western curricula, boarding schools did not recognize traditional ecological knowledge (TEK). Post-secondary education opportunities were only available in Fairbanks, Anchorage, or Sitka, however, TEK or Alaska Native world views were not addressed in science course offerings. Upon gaining the right to provide education at the local level, the North Slope Borough (NSB) of Alaska incorporated Iñupiat educational philosophies into the educational system. The NSB, in partnership with the University of Alaska Fairbanks, established Iḷisaḡvik College, the only tribal college in Alaska. Now independently accredited, Iḷisaḡvik offers 2-yr academic degrees and certificates in Allied Health programs, and is developing science, technology, engineering, and mathematics (STEM) programs. Iḷisaḡvik seeks to broaden STEM education on the North Slope to meet the needs of employers and research in fields such as climate science. Courses bridging TEK and Western science have been developed as a means of introducing STEM education to North Slope students. These courses include summer science camps, workshops, college curriculum, and internships. Relationships between local and visiting educators, scientists, community scholars, and Elders facilitate closing the TEK and Western gap.

¹ Nicholas-Figueroa, L. Barnhardt, R. Duffy, K. Dunlap, K. van Muelken, M. & Middlecamp, C. (2015). Delivering Post-Secondary STEM Education on the North Slope, Alaska: Resilience and Adaption. *International Research in Education*. 3(2), 80-92. doi: 10.5296/ire.v3i2.7555

1.1 Introduction

In order to remain academically competitive with their urban peers, Alaska Native students residing in rural communities need to achieve a degree of competence in science, technology, engineering and mathematics (STEM). Ideally, the combination of STEM competence and traditional knowledge will ensure the longevity of dynamic indigenous cultures in an increasingly technological world. To meet this need, faculty members at Ilisagvik Tribal College conduct workshops and camps with a modular, self-contained format. Student engagement can be encouraged by developing college curricula that incorporates place-based science modules with traditional ecological knowledge (TEK) (Duffy et al., 2011a). The modular format is associated with local science camps targeting youths in grades 7 through 12 as well as traditional undergraduates. The modules provide a practical means of presenting scientific content to rural, remote areas of the Arctic. Students learn from local and visiting scientists, scholars and Elders and integrate scientific concepts with local heritage and cultural experiences. The knowledge gained from integrating STEM content and TEK enables students to become active, informed employees, community members and leaders, a necessity as the extreme Arctic environment interfaces with technology.

Alaska's North Slope is a resource rich region occupying highly diverse coastal Arctic ecosystems. Scientists representing national and state agencies, as well as the oil and gas companies, intently research and monitor the effects of development on the landscape. An excellent vantage point to monitor global change and for national security, Barrow is inundated with scientists and science opportunities. In preparing local youth for employment and

community leadership roles, Iñisagvik Tribal College offers STEM science camps to introduce students to short courses such as biotechnological skills workshops and citizen science projects with the North Slope Borough School District.

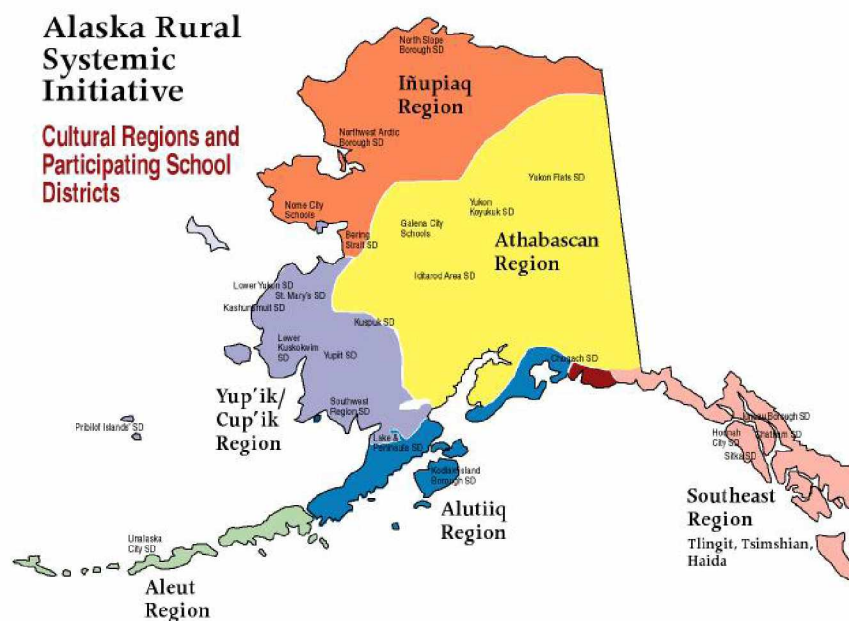


Figure 1.1 Alaska Native languages by region. Alaska Native Knowledge Network, University of Alaska Fairbanks

1.2 Rural Alaska and Educational Philosophy

Data from the 2010 Alaska census indicate a state population of over 710,000 residents of which approximately 290,000 lived in Anchorage (US Census Bureau, 2010). However, most of Alaska (40%) is comprised of small, rural, and isolated communities that range between 25 and 5000 residents (Barnhardt & Kawagley, 2010). These rural communities are predominantly Alaska Native villages with a total population of 90,000 individuals. Divided into six major regions with distinct languages (Figure 1.1), many of these communities are accessible only by

airplane or boat. Over 70 percent of these individuals live and practice their traditional cultures (Barnhardt & Kawagley, 2010), including traditional subsistence lifestyles of hunting, fishing, and gathering.

Alaska Natives in these rural communities rely on subsistence living as a major source of food, clothing, and raw materials. Although in some villages people can purchase provisions at general stores, the major components of their diet include wild plants and berries, fish, caribou, moose, walrus, whales, and other marine mammals. These foods are strongly tied to their cultural and spiritual identities (Barnhardt & Kawagley, 2010).

By living a subsistence lifestyle youth learn values and skills from their Elders. They learn how to read the environment: land, oceans, rivers, and ice from a traditional ecological knowledge perspective. This knowledge, passed down through the generations, is built on continuous observation and provides a rich source of instructional stories.

Patricia L. Cochran, former Executive Director of the Alaska Native Science Commission and former Chair of the Inuit Circumpolar Council, is an Iñupiat raised in Nome, AK and who now resides in Barrow. Interviewed as part of the Wisdom of the Elders radio program (Cochran, 2013), Cochran told listeners:

“One of the things that people forget: traditional knowledge is dynamic; it is not static. The traditional knowledge I know not only came from my Mom and my grandparents, but it’s different, and what I pass on to my grandchildren will be different. Traditional knowledge builds. And that’s what it’s about: it’s just not knowledge from the past; it really builds from what I know today and what generations will teach. So that’s really what traditional knowledge is – it’s living every day (P. Cochran, personal communication, September 11, 2013).”

For Alaska Natives, the environment is their school; the Elders are the teachers; and the young men, women, and children are the students. These practices, which are passed to the next generation, contrast to the cultures of Western societies, especially in terms of spirituality and education. In the 1800's missionaries sought to create educational institutions designed not to enhance the Native ways of knowing, but to replace them. Translations were difficult between Alaska Native languages and English; therefore loss of language meant loss of traditional education. Children were sent away to boarding schools, away from their parents and grandparents, a significant disruption to their multi-generational education. As a result of the Molly Hootch legal decision (*Tobeluk v. Lind*)², boarding schools were eventually replaced by a Western style, state-funded school system. Up to the early 1900's, Native knowledge and Western science were classified as two mutually independent systems (Barnhardt, 2005; Figure 1.2). Steven Dinero (2004) discussed the difficulties associated with the Western educational style: Western curricula are not conducive to meet the needs of the Native societies; rather they are means to transformation to Western societal norms. This "social control" can often lead to "culturally insensitive curricula and pedagogy."

1.3 North Slope Borough and Education

Occupying 15 percent of Alaska's land mass (89,000 square miles), the North Slope is home to 10,000-plus residents, the majority of whom (76.4 percent) are Iñupiat Eskimo (Shepro, 2010). North of the Arctic Circle, North Slope Borough is made up of eight villages: Anaktuvuk Pass; Atkasuk; Barrow; Kaktovik; Nuiqsut; Point Hope; Point Lay and Wainwright (Figure 1.3). The

² Prior to the *Tobeluk v. Lind* decision, lack of local, quality secondary school facilities resulted in a boarding school model for high school students. Students who chose to continue their education beyond elementary school were immersed in an educational setting that was both geographically and culturally removed from their place of origin. This situation often led to mistreatment of Alaska Native students and a high dropout rate (Haycox, 2006). The signing of the *Tobeluk Dissent Decree* committed the state of Alaska to build high schools in the local communities.

largest populated village is Barrow with over 4,500 residents and the next largest village, Point Hope, has approximately 700 residents. Point Lay is the smallest village with approximately 200 residents.

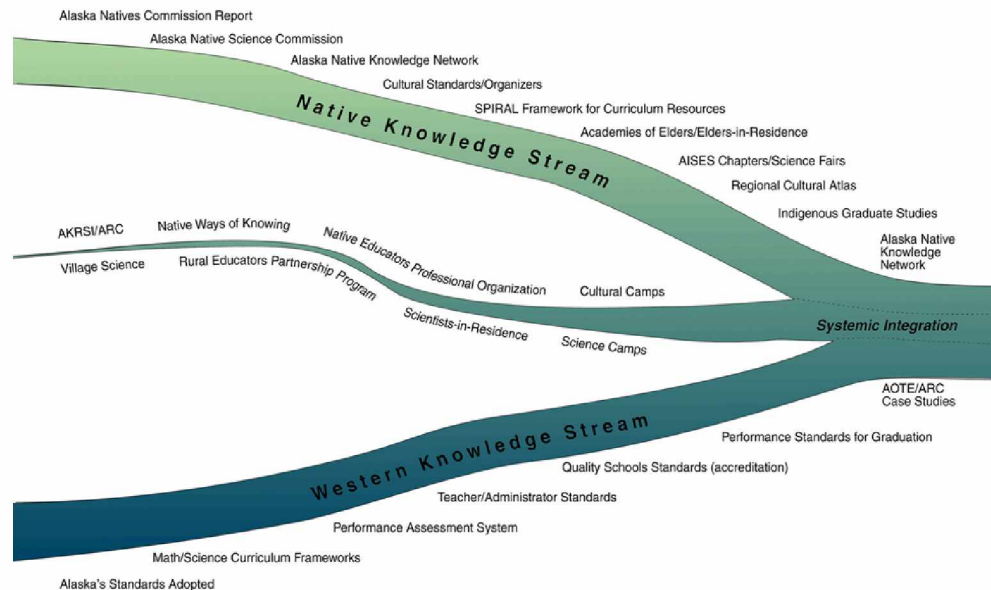


Figure 1.2 Two independent knowledge systems: Native knowledge stream and Western knowledge stream. Alaska Native Knowledge Network (Barnhardt, 2005)

The North Slope Borough was created shortly after the 1971 passage of the Alaska Native Claims Settlement Act (ANCSA). This major political event unified the North Slope villages and provided a framework for the borough to provide economic, education, social service, and other cultural benefits, as well as the funding to deliver these services. The Iñupiat people decided that regulation, taxation, as well as the educational needs of their people should be supported by their own local government (Barnhardt & Harrison, 1993). A few years after assuming this control, Eben Hopson, the first mayor of the Borough, made the following observation:

“Today we have control over our educational system. We must now begin to assess whether or not our school system is truly becoming an Iñupiat school system, reflecting Iñupiat educational philosophies, or, are we in fact only theoretically exercising “political control” over an educational system that continues to transmit white urban culture? Political control over our schools must include “professional control” as well, if our academic institutions are to become an Iñupiat school system able to transmit our Iñupiat traditional values and ideals (Hopson, 1977).”

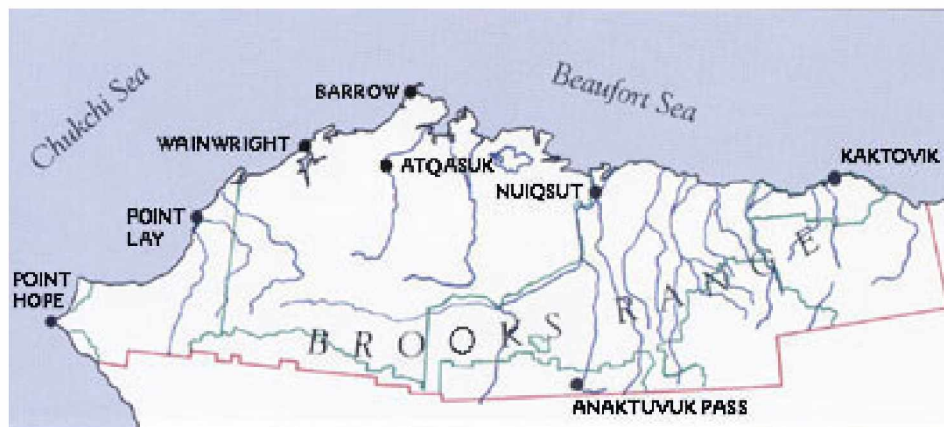


Figure 1.3 Eight villages of the North Slope Borough. Education through Cultural and Historical Organizations (<http://www.echospace.org/articles/387/print.html>)

In order to facilitate “professional control,” leaders believed the schools had to be staffed with Iñupiat teachers and administrators and this, in turn, constituted merging Iñupiat educational philosophies with those of Western education at the post-secondary level (Barnhardt, 1999; Figure 1.2). In 1986, the North Slope Borough created the North Slope Higher Education Center. The North Slope Borough partnered with the University of Alaska Fairbanks (UAF) to facilitate this transition from a center to a tribal college, and for the new college to operate until independent accreditation was achieved. The North Slope Higher Education Center’s Board and

the North Slope Borough Assembly changed the institution's name to Arctic Sivunmun Iḷisaġvik College in 1991. In 1995, the North Slope Borough established by ordinance the Iḷisaġvik College Corporation.

In 2006, after two decades of effort, Iḷisaġvik College was recognized as a Tribal College, the first and only Tribal College in Alaska. Located in the former Naval Arctic Research Laboratory facilities, Iḷisaġvik College provides academic, vocational, and technical education with one of its missions being the incorporation of traditional values and traditional ways of knowing in STEM courses. Iḷisaġvik College serves the eight villages of the North Slope and has recently extended services to villages and communities outside of the official borough boundaries.

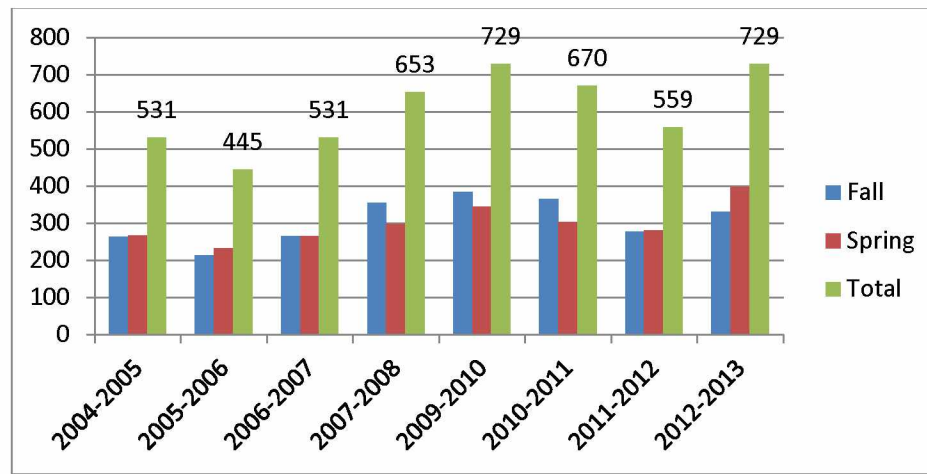


Figure 1.4 Iḷisaġvik enrollment trends from Fall 2004 to Spring 2013. Iḷisaġvik College Institutional Research Report, 2013

Using the 2012-13 as a typical academic year, Iḷisaġvik has a student population, which can be characterized by age, gender, and race. 68% of students enrolled in courses were age 25 and older. The female enrollment was 56% and males 44%. Iḷisaġvik as a tribal college has

maintained the Alaska Native student population of 51%. Enrollment increased from an average of 500 students per year (2004 – 2007) to an average of 675 students per year (2008 – 2013) (Figure 1.4).

Iḷisaġvik's degree programs include General Studies, Business, Iñupiaq Studies, and Allied Health. The Allied Health program is currently the primary STEM related program delivered by the college and strives to meet growing workforce needs. The Associate Degree in Liberal Arts acts as a feeder program to the University of Alaska (UA) System and allows students to remain close to their home and land as they begin their post-secondary education. Iḷisaġvik College continues to improve the foundation science courses necessary for completion of the Liberal Arts degree through the incorporation of TEK. As it plans for future growth in the community, Iḷisaġvik is striving to meet the broad employment demands of expanding resource development thus increasing the likelihood of retaining local talent.

1.4 STEM and Alaska Natives

STEM disciplines are tightly linked to innovation and economics in Alaska. In a report published in the Springboard Program for the Juneau Economic Development Council, Sorenson (2010) describes STEM education goals for Alaskans as 1) an approach that connects several disciplines rather than learning each one separately preparing them for real-life situations; 2) to foster students ability to solve problems; 3) to enhance their learning environments through discovery and; 4) a move to drive STEM literacy into the classrooms for ALL students (Sorenson, 2010). Quality STEM education needs to be delivered and minority students should be recognized in these efforts (Hussar & Bailey, 2008; National Science Board, 2010).

For Alaska and the North Slope, this underrepresented group is essential to both local control of the educational process and the development of a strong workforce. Previous studies concluded that underrepresented minorities of African Americans, Hispanics, and Alaska Native/American Indian (AN/AI) are less likely to be noticed as talented students compared to Caucasians and Asian/Pacific Islanders (Hoffman & Llagas, 2003; Learning Point Associates, 2004; Gandara, 2005; Hussar & Bailey, 2008). Within these underrepresented minorities, AN/AI students have the highest high school dropout rates (Swanson, 2004), and have among the lowest college entrance and retention rates in the country (Devoe & Darling-Churchill, 2008; Hunt & Harrington, 2008). Alaska rural communities, populated primarily by Alaska Natives, are at a further disadvantage as the secondary schools cannot offer a wide range of advanced courses or placement exams.

One remedy was the development of culturally responsive science curriculum as described by Barnhardt and others:

“Culturally responsive science curriculum attempts to integrate Alaska Native and Western knowledge systems around science topics with goals of enhancing the cultural well-being and the science skills and knowledge of students. It assumes that students come to school with a whole set of beliefs, skills, and understanding formed from their experiences in the world. The role of STEM education is not to ignore or replace prior understanding, but to recognize and make connections to that understanding. It assumes that there are multiple ways of viewing, structuring, and transmitting knowledge about the world – each with its own insights and limitations (Figure 1.2). It thus values both the

rich knowledge of Native Alaskan cultures and of Western science and regards them as complementary to one another in mutually beneficial ways (Stephens, 2003; Barnhardt, 2005).”

Students can become involved in gathering and documenting local knowledge and culture by obtaining relevant information from sources such as families, resource people/scholars, Elder groups, or others. This knowledge can be incorporated into modules that can be continuously updated. To better enhance the learning abilities for Alaska Native students, cultural relevance can be integrated into STEM curriculum (Duffy et al., 2009; Duffy et al., 2011b).

1.5 Partnerships

Beginning in 1995 and supported by the National Science Foundation, the University of Alaska Fairbanks (UAF) and the Alaskan Federation of Natives (AFN), in partnership with Alaska Native communities, endeavored to create a research-based STEM curriculum. This initiative, the Alaska Rural Systemic Initiative (AKRSI), was aimed at fostering a connection between the current abstract scientific pedagogy and practical Indigenous knowledge. In AKRSI’s final report (AKRSI, 2005), the Alaska Native enrollment at the state university, UAF, showed significant increased enrollment in biology and wildlife, chemistry and biochemistry, geology, and mathematics. The enrollment in these STEM fields increased from 36 in 1994 to 84 in 2000 (AKRSI, 2005). The selection of the STEM majors illustrated and supported the concept that relevance to everyday activities and place-based issues could connect science to rural Alaska Native students. This initiative also demonstrated the importance of establishing an explicit pathway in which rural students are exposed early and continuously to relevant STEM ideas. This pathway is a good example of rural Alaska’s adaptation and cultural resilience.

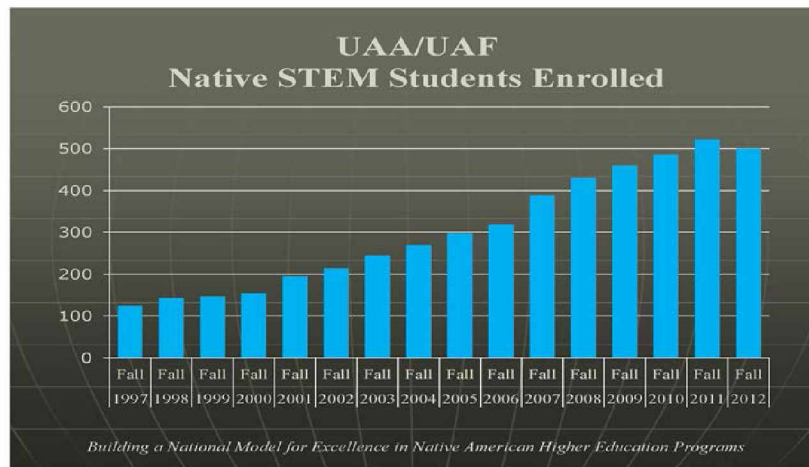


Figure 1.5 Alaska Native STEM students enrolled at UAA/UAF from Fall 1997 to Fall 2012. Alaska Native Science and Engineering Program (www.ansep.net/statistical-data.html)

More recently, Alaska Native STEM students enrolled in the UA system showed a steady increase from fall semester 1997 with 100 students to 500 plus students in fall semester 2011 (Figure 1.5). Graduation rates increased proportionately to enrollment (Figure 1.6). Many of these Alaska Native STEM graduates began their education at community colleges, including Iḷisaḡvik. These pathway students are now populating graduate programs.

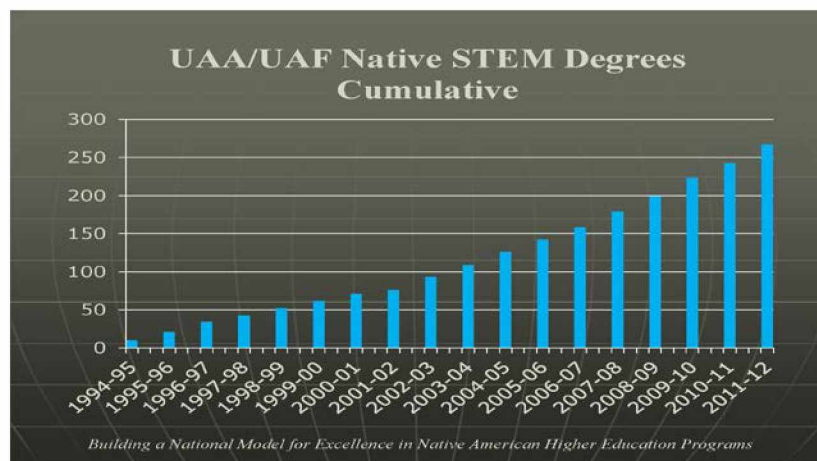


Figure 1.6 Cumulative UAA/UAF Alaska native STEM Degrees, 1994 – 2012. Alaska Native Science and Engineering Program (<http://www.ansep.net/statistical-data.html>)

Iḷisaḡvik College promotes STEM education to North Slope secondary school students through a curriculum that follows the Iñupiaq Learning Framework (ILF) and incorporates Iñupiat heritage and traditions into state and federal guidelines. The curricula is supported by the STEM science camps which introduce students to 1) short courses such as biotechnological skills workshops and 2) citizen science projects with the North Slope Borough School District. In partnerships with the Ukpeaḡvik Iñupiat Corporation Science and the North Slope Borough Department of Wildlife Biology, Iḷisaḡvik Tribal College faculty members are developing internships for college and high school students.

One recent and highly successful activity, the Iḷisaḡvik STEM high school summer camp, was initiated in 2011. The camp was located at campus facilities in Barrow and provided students with college credit upon completion. This camp was run for middle school students in 2012 – 2013. This camp was a model for a second STEM camp, *Climate and Permafrost Changes on the North Slope: In Cultural Context*, for high school students in 2012 and 2013. Culturally relevant, these summer science courses emphasized the impacts of climate change within the North Slope Borough and were the result of a partnership formed between Iḷisaḡvik, UAF, and supported by the American Indian Higher Education Consortium, University of Illinois at Urbana-Champaign, and Smithsonian Institution's National Museum of the American Indian.

A powerful example of how partnerships can effectively integrate Western science and TEK principles occurred during the 2012 summer camp. A visiting educator was teaching Aurora Alive, a comprehensive UAF developed multimedia course with over 100 hands-on math, science, and physics lessons that taught the science and research behind the Aurora borealis. The students were engaged. The majority of the students live where the Aurora is

visible on dark, clear nights. Two Iñupiat Elders visited the camp and spoke about the aurora and retold the associated legend that encouraged children to return home at a reasonable hour. They sang a song in Iñupiaq, to the tune of jingle bells, with the students joining in.

In addition, the Elders discussed current environmental changes: thinning Arctic Ocean ice that affects the spring whale hunts and the long fall fishing season due to late freezing lakes. They have observed willows growing taller and bushier while salmonberries and crow berries are found growing further north. The people are catching more salmon than they did growing up. By the end of the class period, the students began to speak about the changes they have seen in their lifetimes. This engaging dialogue between students and Elders sparked student interest and resulted in greater discussion of ecological change. The Elders encouraged the youth to study science and use their cultural knowledge to come to their own conclusions.

1.6 Iḷisaḡvik College STEM Curriculum Adaptation

Iḷisaḡvik College science courses consisted of the typical courses one would see at most universities or community colleges. This type of abstract science course did not generate student interest. For example, a general education science course listed under Geological Science, “An Introduction to Earth Science,” had no enrollment the last several offerings. In contrast, a newly developed course, “Indigenous Science and Traditional Ecological Knowledge,” listed under Geological Science had 3 and 5 students in its first two offerings, respectively. The classical geology in the introductory course is now presented in a place-based format.

A second new course, “Climate Change and the North Slope Community,” engages students in the changes in climate and permafrost specifically on the North Slope. The students involve Elders through interviews to acquire their perspectives, experiences, and observations on this subject. These courses offer a different insight on how a student can study science while at

the same item apply this science to what is relevant and important to their village or community. They fit the model suggested by Iñupiat Elder Patricia Cochran: knowledge grows with everyday environmental experiences.

1.7 Conclusion

STEM education is important throughout the United States. However, African Americans, Hispanics, and Alaska Native/American Indian enrollment in STEM curricula are underrepresented. In rural communities, such as Alaska's North Slope, advanced education in general, and STEM in particular is improving. The provision of STEM education to rural Alaska students should integrate Western science and Indigenous knowledge. This can be accomplished by introducing STEM to youth and undergraduates through college curriculum, workshops, summer camps, and discussions with Elders.

Workshops providing culturally relevant hands-on activities related to the environment, land animals, and marine animals can be developed and delivered on weekends to the local youth throughout the school year and in summer camps. This weekend exposure may lead to greater interest in science and provide a better foundation for college courses. During the summer science camps, Elder participation can be extended beyond casual conversation. Elder scholars and visiting scientists can "team up" and instruct together. Co-presentation in the classroom, on field trips and during activities would emphasize the importance of learning a concept from both the Western and Indigenous perspective. Elders can participate in existing and new college curricula through class visits and interviews. It would be a beneficial adaptation for one Elder to provide guidance of local Indigenous knowledge for a particular STEM subject throughout the course of the semester.

Acknowledgements

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References

- AKRSI. (2005). Alaska Rural Systemic Initiative Final Report. Retrieved from <http://www.ankn.uaf.edu/download/AKRSI2005FinalReport.doc>
- Barnhardt, R. (1999). *Culture, Chaos and Complexity: Catalysts for Change in Indigenous Education*. Retrieved from <http://ankn.uaf.edu/Curriculum/Articles/BarnhardtKawagley/ccc.html>
- Barnhardt, R. (2005). *Culture, community, and place in Alaska Native education. Democracy and education*. Retrieved from <http://ankn.uaf/Curriculum/Articles/RayBarnhardt/CultureCommPlaceANE.html>
- Barnhardt, R. and Harrison, B. (1993). Developing Tribal Education Strategies in Indigenous Communities. In *Discourse: the Australian Journal of Educational Studies*. Retrieved from <http://ankn.uaf.edu/Curriculum/Articles/TribalEducationStrategies.html>
- Barnhardt, R., & Kawagley, O. A. (2010). *Alaska Native Education Views From Within*: Alaska Native Knowledge Network, Center for Cross-cultural Studies, University of Alaska Fairbanks.
- Cochran, P. (2013). Wisdom of the Elders Radio Program S4E1, Wisdom of the Elders, Inc.
- DeVoe, J., & Darling-Churchill, K. (2008). Status and trends in education of American Indians and Alaska Natives. (NCES 2008-08). Washington, DC: National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education. Retrieved from http://nces.ed.gov/pubs2008/2008084_1.pdf
- Dinero, S. (2004). The Politics of education provision in rural Native Alaska: the case of Yukon Village. *Race Ethnicity and Education*, 7(4), 401-419. <http://dx.doi.org/10.1080/1361332042000303405>
- Duffy, L., Middlecamp, C., Godduhn, A., & Fabbri, C. (2009). Using Culture, Policy and Traditional Knowledge to Improve Engagement in Science Courses. *American Journal of Applied Sciences*, 6(8), 1560-1566. <http://dx.doi.org/10.3844/ajassp.2009.1560.1566>
- Duffy, L., Godduhn, A., Fabbri, C., van Muelken, M., Nicholas-Figueroa, L., & Middlecamp, C. (2011a). Engaging Students in Science Courses: Lessons of Change from the Arctic. *Interchange A Quarterly Review of Education*, 42(2), 105-139.
- Duffy, L., Godduhn, A., Dunlap, K., van Muelken, M., & Middlecamp, C. (2011b). Sustainability and Chemistry: Key concepts in an Arctic focused interdisciplinary course. In Sustainability in the Chemistry Curriculum, (Middlecamp, C and Jorgenson, A eds) American Chemical Society Symposium, 1087 (pp. 98-112). Washington, DC.
- Gandara, P. (2005). Fragile futures: Risk and vulnerability among Latino high-achievers. Princeton, NJ: Policy Evaluation and Research center, Educational Testing Service. Retrieved from <http://www.ncrel.org/gap/studies/allstudents.pdf>

- Haycox, S. (2006). *Alaska: An American Colony*. University of Washington Press. p. 285. Seattle, WA.
- Hoffman, K., & Llagas, C. (2003). Status and trends in the education of blacks (NCES 2003-034). Project Officer: T.D. Snyder. National Center for Education Statistics. Washington, DC: U.S. Department of Education. Retrieved from <http://nces.ed.gov/pubs2003/2003034.pdf>
- Hopson, E. (1977). Inupiaq education. *In* R. Barnhardt (Ed.), *Cross-cultural issues in Alaskan education* (pp. 3-6). Fairbanks, AK: Alaska Native Knowledge Network, University of Alaska. Retrieved from <http://www.ankn.uaf.edu/Curriculum/CXCS/Issues1/Hopson.html>
- Hunt, B., & Harrington, C. (2008). The impending education crisis for American Indians: Higher education at the crossroads. *Journal of Multicultural, Gender and Mineral Studies*. 2(2) , 1-11. Retrieved from <http://www.scientificjournals.org/journals2008/articles/1393.pdf>.
- Hussar, W., & Bailey, T. (2008). Projections of education statistics to 2017 (NCES 2008-078). National Center for Education Statistice, Institute of Education. Washington, DC; U.S. Department of Education. Retrieved from <http://nces.ed.gov/pibs2008/2008078.pdf>
- Learning Point Associates. (2004). All students reaching the top: Strategies for closing academic achievement gaps. Naperville, IL: North Central regional Educational Laboratory. Retrieved from <http://www.ncrel.org/gap/studies/allsdudents.pdf>
- National Science Board. (2010). Higher education in science and engineering. *In* Science and engineering indicators 2010 (pp. 13). Arlington VA: National Science Foundation. Retrieved from <http://www.nsf.gov/statistics/seind10/pfg.seind10.pdf>.
- Shepro, C. (2010). The North Slope Borough Economic Profiles and Census Reports. Retrieved from http://www.north-slope.org/departments/mayorsoffice/census_data_2010.php
- Sorenson, B. (2010). Alaska STEM Education and the Economy, Report on the Need for Improved Science, Technology, Engineering and Mathematics Education in Alaska. pp. 8. Retrieved from <http://www.jedc.org/research-library-reports-studies-jedc>
- Stephens, S. (2003). Handbook For Culturally responsive science curriculum. Fairbanks, AK: Alaska Native Knowledge Network. Retrieved from <http://www.ankn.uaf.edu/publications/handbook/>
- Swanson, C. (2004). Who graduates? Who doesn't? A statistical portrait of public high school graduation, class of 2001. Washington, DC: The Urban Institute. Retrieved from www.urban.org/UploadedPDF/410934_WhoGraduates.pdf
- US Census Bureau. (2010). US Department of Commerce. Retrieved from <http://quickfacts.census.gov/qfd/states/02000.html>

Chapter 2

Iḷisaḡvik Tribal College's Summer Climate Program: Teaching STEM Concepts to North Slope Alaska High School and Middle-School Student¹

Abstract

The incorporation of informal science modules with traditional ecological knowledge (TEK) engages students in Science, Technology, Engineering, and Mathematics (STEM) courses. During the summers of 2012 – 2015, Iḷisaḡvik Tribal College, located in Barrow, AK, hosted an average of 12 rural Alaska Native middle-school and high school students per year in the college's summer STEM program called "Climate and Permafrost Changes on the North Slope: In Cultural Context." Teaching the carbon cycle as a core concept, this 2-week STEM program examined climate change and its effects on the local landscape from a multiple of perspectives. Elders shared their observations and experiences associated with climate change. Local and visiting scientists gave presentations and taught through games, hands-on laboratory simulations, and practical field work – all relevant to the camp's science content. Pre-assessments and post-assessments using the Student Assessment of Learning Gains measured student interests and conceptual understanding. Students developed and enhanced their understanding of science concepts, and, at the end of the camp, could articulate the impact of climactic changes on their local environment.

¹Nicholas-Figueroa, L. Hare, R. van Muelken, M. Duffy, L. & Middlecamp, C. (November 2, 2016). Iḷisaḡvik Tribal College summer climate program: teaching STEM concepts to North Slope Alaska high-school and middle-school student. *Journal of Environmental Studies and Science*. p. 1-10. Retrieved from <http://link.springer.com/article/10.1007/s13412-016-0413-6>.

2.1 Introduction

Located 300 mi north of the Arctic Circle, the North Slope Borough is home to approximately 10,000 people residing in eight villages (Figure 2.1). The majority of the residents are Iñupiat Eskimo (>75 %) whose rich cultural heritage exceeds 10,000 years (Shepro, 2010). According to the official website of the North Slope Borough (NSB, 2016), “Today, Iñupiat still look to the land for cultural and economic sustenance.” While the Iñupiat have embraced economic and technological changes, they additionally depend on whaling, hunting, and fishing for cultural identity and much of their food supply. These practical skills and value or traditional ecological knowledge (TEK) are passed from elders to youth, providing a dynamic cultural connection that uses observational methods and storytelling to examine environmental change. Global warming, a growing community concern, for example, may have significant impacts on the local environment and waters. Changes in ice are already occurring with the high rate of sea-ice decline leading to unstable ice conditions, which could create tremendous dangers during the winter hunting season for seals, walrus, and whales. Erosion, thawing permafrost, and changes in plant and animal migration are also affected by a warming climate.

Over the last 60 years, Alaska has experienced a 6 °Fahrenheit (F) increase in winter temperatures and a 3 °F increase overall, twice that of the rest of the planet (EPA, 2015). On the North Slope, the resultant ecological changes have been both positive and negative. Personal witnesses to global warming, North Slope youth are observing significant changes to the landscape. Although local and national leaders are addressing climactic concerns and adaptation and resilience protocols are being formed, it is imperative that North Slope youth are informed as well. Knowledge of current climate science theory and practice can give students the confidence needed to become active members and voices within their communities when strategic choices to

mitigate climate change impacts are required (Perkins et al. 2014). Alaska Native youth often are confronted with straddling the fence in a world of technological advances and traditional knowledge. This program is designed to enhance student learning by blending lessons of Western science and discussions with Elders on TEK on environmental issues associated with climate change. Self-assessment is utilized to help determine if students have an increase of knowledge at the end of the program.

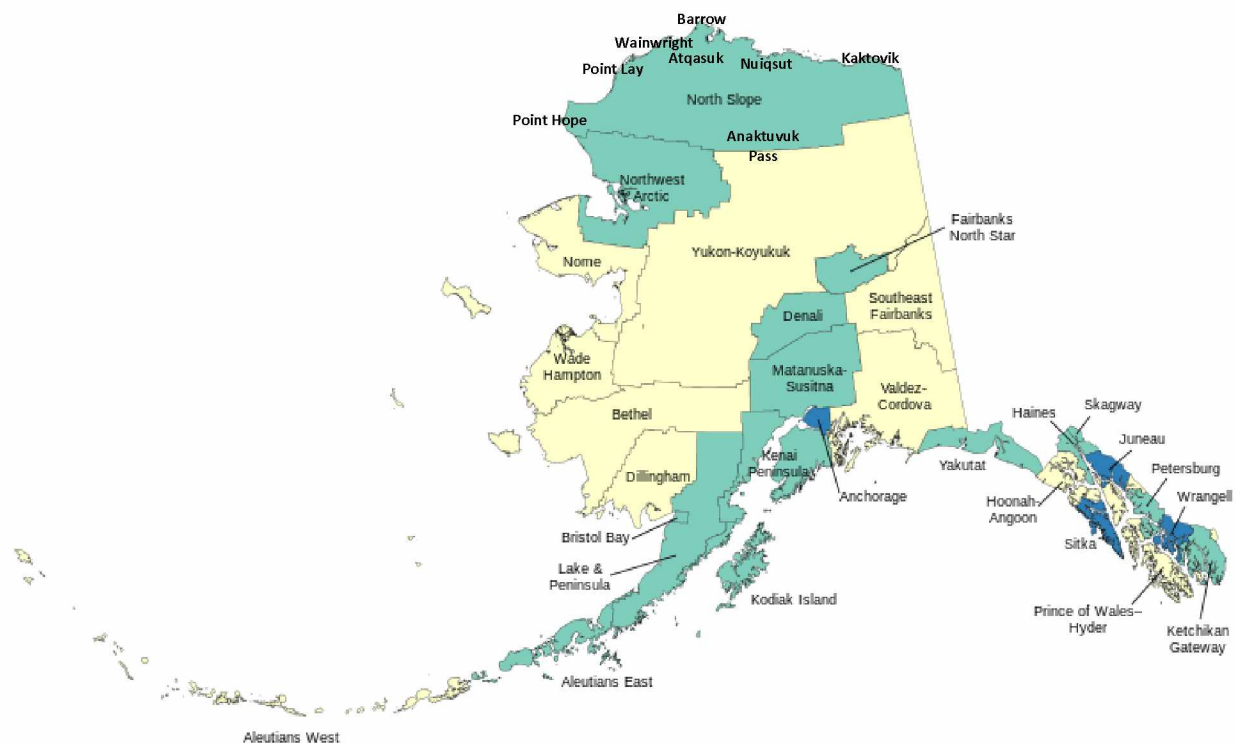


Figure 2.1 Map of the North Slope Borough (NSB) used with the permission from the NSB Department of Planning/GIS division (source, <http://www.north-slope.org/assets/images/uploads/NSBCensus2010.pdf>). Barrow, AK, is the most populated village averaging around 4500 people, 61 % being Alaska Native. The remaining village (Anaktuvuk Pass, Atkasuk, Kaktovik, Nuiqsut, Point Hope, Point Lay, and Wainwright) populations range from 900 to 200 people, 90 – 95 % being Alaska Native.

Up to the early 1900s Native knowledge and Western science were classified as two mutually independent systems (Stephens 2000; Barnhardt 2005). By the nineteenth century, an extensive amount of literature compared these two systems. While Western science is

transmitted through academics and literature, on the contrary, traditional knowledge is transmitted through generations of oral story telling by Elders (Mazzocchi, 2006; Medin and Bang, 2014). Isolation of the objects of study, or separation from nature, is common in Western science, while traditional knowledge consistently depends on its environment and its distinct conditions (Nakashima and Roué, 2002). As pointed out by Lowan (2012), tensions between Western and Indigenous science have led to scholars such as Gregory Cajete, Ray Barnhardt, and Angayuqaq Oscar Kawagley to seek a common ground, “an existential and epistemological meeting place” between traditional Native knowledge and Western science (Figure 2.2). Today, relationships between local and visiting educators, scientists, community scholars, and Elders can facilitate closing the TEK and Western science gap.

Climate and Permafrost Changes on the North Slope: In Cultural Context program was developed through a partnership with Iñisagvik Tribal College, the University of Alaska Fairbanks, and supporting collaborators. This program is a short two-credit course but runs in an interactive manner. Student selection was primarily based on students’ interest in science, but anyone was eligible to apply. For example, one student’s main interest was in culinary arts, but she had indicated that she was very concerned about the environmental changes occurring in her village due to climate changes. Her village, Shishmaref, is facing grave coastal erosion that could lead to the necessity to evacuate the entire community. As we were looking for an increase in knowledge, GPA was not a factor in the selection of students. With Barrow being the largest community with the most student applicants, we did assure that our selection of students was from several different rural villages to include one or two outside of the North Slope Borough.

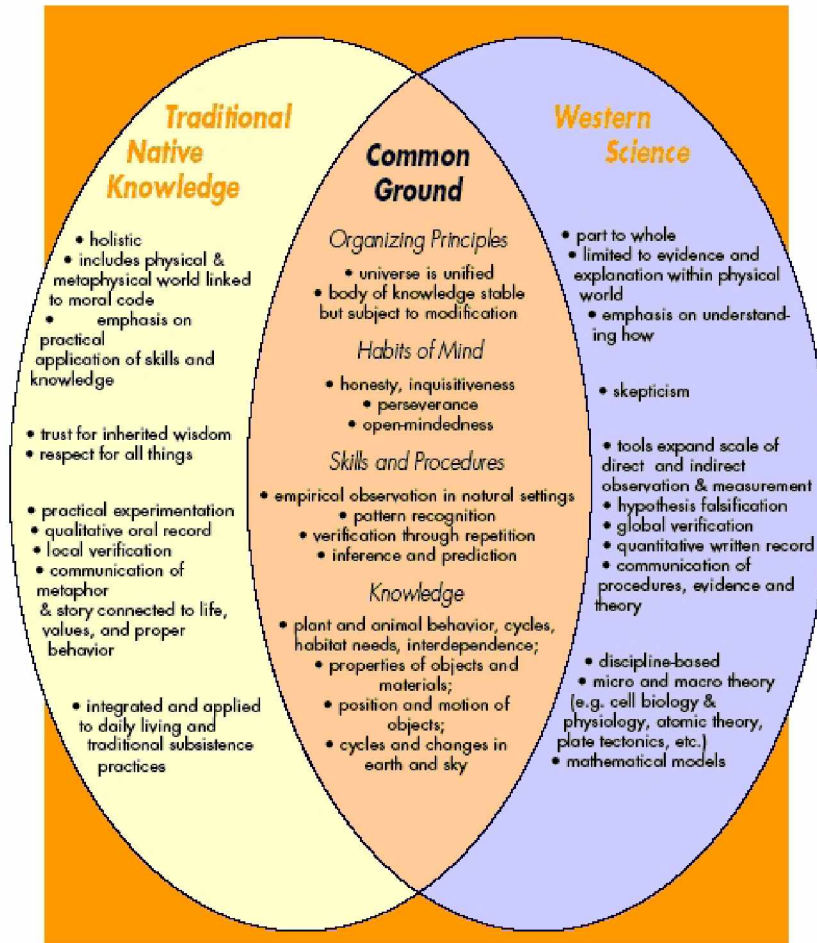


Figure 2.2 From the Handbook for the culturally responsive science curriculum (Stephens 2000)

The course curriculum consists of modules that address Arctic ecology, the carbon cycle, natural resources, global warming, and the physical impacts of a warming climate (Figure 2.3). Modules are a practical means of presenting scientific content to varying age groups equivalent to grades 7 – 12 (Nicholas-Figueroa, et al. 2015). Informal science, with a strong layer of TEK, encourages student engagement; the modules reflect the students' rural upbringing and their interaction and expertise with technology (Duffy, et al. 2011a; Nicholas-Figueroa, et al. 2015). Lessons, such as the physical impacts of a warming climate, included a scientific presentation, lab activities and/or field trips, and discussions with Elders leading to dynamic interactions between the students, scientists, and Elders.



Figure 2.3 Coastal erosion, Barrow, AK. Photograph by Linda Nicholas-Figueroa

2.2 Methods

2.2.1 Student assignments

Students attending the camp were given out-of-class assignments, maintained a daily journal, wrote a minimum 500-word essay, and delivered a presentation at the end of the camp. Assignments were based on the materials that covered the periodic table, elements, carbon, combustion, greenhouse gases, and climate change. The students were required to take daily notes in their journals on the scientific lectures, hands-on/lab activities, Elder discussions, and field trips. The journals were collected and returned with informational comments that supplemented their notes, enhancing the learning process. Students were encouraged to write their essays on topics of interest to them. The students prepared a public presentation integrating the knowledge gained from the assignments, scientists, Elders, and fieldtrips.

2.2.2 Meeting with scientists

Local and visiting scientists presented information to the students through presentations, hands-on activities, laboratory simulations, and games. Foundational topics such as carbon chemistry, weather and climate, greenhouse gases, atmospheric CO₂, and global warming were

presented by instructional faculty: Linda Nicholas-Figueroa, Ilisagvik College; Drs. Rebekah Hare and Lawrence Duffy, University of Alaska Fairbanks; Dr. Cathy Middlecamp, University of Wisconsin-Madison; and Dr. Bob Rabin, NOAA/National Severe Storms Laboratory. Visiting presenters provided a breadth of topics emphasizing the impacts and issues associated with a changing Arctic (Table 2.1).

2.2.3 Meetings with Iñupiat Elders

Exposure to traditional knowledge occurred through the lessons with local Elders. Information gained from this experience will help the students to develop and enhance their personal understanding of the significant relationship and impact of climate change on their local villages/communities. These were two-way discussions between the Elders and students. There was no set format for the discussions, allowing the Elders to speak freely and adapt the conversations to student inquiries (Table 2.2).

2.2.4 Field Trips

An integral camp component, field trips demonstrated practical applications of conceptual topics covered by both the scientists and Elders. Students were exposed to real-time activities that correlated with lessons learned and proved concrete examples of Science, Technology, Engineering, and Mathematics (STEM) concepts learned in class. These outings additionally demonstrated the scientific importance of the North Slope Borough to scientific inquiry. Table 2.3 lists the sites visited, the role played in the Arctic and/or local community, and any activities that the students observed/performed during their visit.

Table 2.1 Student interaction with visiting and local scientists.

Scientist	Affiliation	Presentation Topic
Dr. Christian Andersen	University of Texas at El Paso	Local lakes: understanding of long-term changes in biological, hydrological, and chemical systems due to climate change.
Dr. Robert Hollister	Grand Valley State University	Vegetation: the importance of global warming and the response of changing tundra.
Dr. Jenny Cunningham	University of Missouri	Shoreline birds: change in migration patterns with warming climate.
Dr. Debendra Das	University of Alaska Fairbanks	Permafrost: the effects of thawing permafrost on infrastructure.
Dr. Craig George	Department of Wildlife Management, Barrow AK	Bowhead whales: early plankton bloom may change feeding patterns.
Dr. Robert Sudyam	Department of Wildlife Management, Barrow AK	Beluga whales: offshore drilling can change migratory patterns.
Dr. Justin Bagley	University of Illinois	Land cover change/global food production and climate change: how will food and energy crops meet global demands, and how those demands will impact the environment.
Dr. Eric Wilkman	University of California San Diego	Biogeochemical cycles: climate change and the role of greenhouse gases in the atmosphere, the carbon cycle and the roles of plants and microbes.
Dr. Katherine McEwing	University of Sheffield, UK	
Dr. Chris Cuomo	University of Georgia	Permafrost and thawing lakes as witnessed by elders, hunters and berry pickers.
Dr. Wendy Eisner	University of Cincinnati	

Table 2.2 Student interaction with North Slope Borough Elders

Elder	Affiliation	Presentation Topic
Mr. James Nageak	Iñupiat History, Language and Culture Commission and Iñisaġvik College Board of Trustees	The dilemma of roads: there is a proposal to build a road to Anaktuvuk Pass. This could be a positive economic impact as foods and other goods would not have to be flown in versus the potential impacts of loss of wildlife and cultural integrity.
Ms. Ida Olemaun	Arctic Slope Regional Cooperation (ASRC) Board of Directors	Tourism and culture: with the Northwest Passage opening up, tourism is on the rise. This can be economically beneficial, but such things like cruise ships can cause concerns for the ecological environment and culture.
Mr. Nate Olemaun	Whaling Captain	Sea ice loss: storms are becoming more frequent due to the loss of sea ice, which leads to beach and land erosion.
Ms. Martha Stackhouse	Iñisaġvik College Coordinator for Teachers of the Arctic	North Slope plants: invasive plant species are moving North bringing in more berries, but some new tall grasses might be harmful for the native plant species
Mr. Robert Suvlu	Uquautchim Uglua (Early Childhood Learning) Iñupiaq Culture-Based Coordinator at Iñisaġvik College	Traditional knowledge: importance of learning how to read and respect the environment and paying close attention to the rapid environmental changes are crucial for adaptation.
Mr. Eugene Brower	Arctic Slope Regional Corporation Board of Trustees and President of Barrow Whaling Captains Association	Thinning sea ice and ice-cellars: dangerous conditions during spring whaling, which occurs on the edge of the ice. Most hunted meats (whale, caribou, seal, and walrus) are stored in ice cellars. Foods stored in ice-cellars are spoiling due to melting permafrost.

Table 2.3 Program field trips

Agency Visited	Agency Role	Field Trip Activities
The National Oceanography and Atmospheric Administration (NOAA) – Earth System Research Laboratory (ESRL) – Global Monitoring Division (GMD)	The GMD monitors atmospheric gases such as carbon dioxide, methane, other trace elements, and aerosols that can alter the Earth's climate. This research provides information for climate projections and scientific support for society's to make informed decisions (NOAA, ESRL, GMD, 2015).	Students set up an air flask sample and completed a pump sample. They completed systems' check sheets that familiarized them with the instrumentation and the technician's job requirements; they heard cloud formation and ozone layer presentations; completed observations of the ozone layer and watched a video detailing greenhouse gasses.
The Department of Energy/Atmospheric Radiation Monitoring (ARM)	The ARM Climate Research Facility collects data from a variety of sources and scientists use these data to research and monitor atmospheric radiation and cloud coverage, each having an impact on global climate change (Dept. of Energy, 2015).	Students observed instrumentation such as the Sky Radiation radiometer, which provides information about the solar, infrared, and ultraviolet radioactive energy exchange on the North Slope of Alaska.
The NOAA National Weather Service (NWS) Alaska Region	The NWS covers the state of Alaska and its surrounding waters. The information collected includes hydrology, volcanic ash, tsunamis, daily and long term weather patterns, and climate predictions. The Barrow NWS launches a weather balloon with attached weather instruments twice daily. The collections of weather trends are becoming increasingly more sensitive (NOAA, NWS, 2015).	Students launched the weather balloon. They also watched scientists demonstrate how they take, record, augment, and disseminate aviation observations (METAR) using the Automated Surface Observing System (ASOS). They also discussed sea ice observations, upper-air RAWINSONDE (weather instruments sent aloft by weather balloons) observations and how all of these observations are tied together to produce local and short range and long range weather forecasts. The information gained through these observations is used in climatological studies.

2.2.5 Assessment

The Student Assessment and Learning Gains (SALG) (Seymour et al., 2000; SALG 2013), a student survey instrument developed by the Science Education for New Civic Engagements and Responsibilities (SENCER) project, was used both at the beginning and end of the camp. SENCER is a national STEM curriculum reform project initiated in 2000 with funding from the National Science Foundation. Students took a SALG pretest survey at the beginning of the camp and repeated it as a post-test. The analysis focused on student self-assessment of understanding of how topics relate to (1) greenhouse gases and the carbon cycle, (2) burning of

fossil fuels, (3) their village, and (4) other real-world issues. The six unit Likert scale response options to a statement were 1: not applicable; 2: not at all; 3: just a little; 4: somewhat; 5: a lot; and 6: a great deal. Using the SENCER rubric is like performing a mental audit; each student makes a qualitative assessment of their knowledge or understanding of the issue. The instructional faculty can view the summation of the student gains as follows; not observed (scales values 1 or 2), basic (scale values 3 or 4), a lot (advanced, scale value 5, greater presence of knowledge), and a great deal (transformative, scale value 6, sees relationships). The SALG instrument does not identify individual students and automatically calculates means and standard deviations and generates graphs of the data (Duffy et al. 2011b).

2.2.6 Conference attendance

Many rural Alaska Native villages are only accessible by airplane rendering travel difficult and expensive. However, it is important for rural Alaska Native students to travel and to be exposed to scientific or other academic conferences. Conference attendance is a positive way to enhance and reinforce the students' learning gains as they interact with scientists and other students from many different geographical regions. Two conferences were selected for the students to attend: the 18th Inuit Studies Conference and the Society for the Advancement of Chicanos/Hispanics and Native Americans in Science National Conference. Both conferences offer students the opportunities to gain soft skills such as learning how to communicate scientific data.

2.3 Results

Using SALG assessment tool, students reported how class activities such as lectures, discussions with Elders, and field trips helped their comprehension of the topics discussed (Table 2.4). Students report a general increase in learning about all topics with the exception of “what global warming is.”

Table 2.4 Mean and standard deviation values of questions answered by students prior to the beginning of camp and answers to the same questions at the end of camp

Topic	Mean Pre-test	STD Pre-test	Mean Post-test	STD Post-Test
Presently I understand...				
How elements are organized on the periodic table	3.9	0.83	4.1	1.25
The burning of methane*	3.2	1.67	4.8	1.04
What greenhouse gases are*	4.6	1.41	5.8	0.46
The differences between weather and climate	4.9	1.13	5.6	0.74
What global warming is	5.2	0.89	5.2	1.16
Why air is monitored	4.2	1.75	4.5	1.31
The importance of permafrost	5.1	0.83	5.5	0.76
What biogeochemical cycles are*	2.2	1.04	3.8	0.89
How topics covered can relate to my village*	4.5	0.93	5.6	0.74
How studying the subject helps people address real world issues	4.8	1.04	4.9	1.13

*Significant at $p < .05$

Students reported the significant learning gains for “the burning of methane” ($p \leq 0.01$) and “what are biogeochemical cycles” ($p \leq 0.002$). Figures 2.4 and 2.5 illustrate the gain in knowledge for the understanding of “what greenhouse gases are” ($p \leq 0.01$) and “how these topics can relate to my village” ($p \leq 0.009$).

Using assignments, journal entries, and an essay, the students created presentations delivered to Iḷisagvik College staff and community members. Each student selected an issue of personal interest and learned presentation organizational and public speaking skills. Students were evaluated in these areas; however, the majority of the grade was based on knowledge of content. Table 2.5 lists the titles of the student presentations.

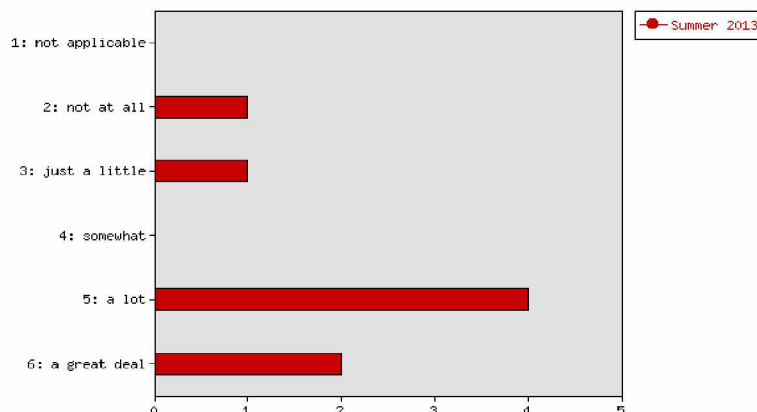
2.4 Discussion

Understanding the carbon cycle and its impact on climate change was the recurrent theme of the 2-week program. Instructors Middlecamp, Duffy, Nicholas-Figueroa, and Hare introduced the concept of the carbon cycle and spent 2 days reinforcing the concept through a variety of activities. The message was threefold: (1) carbon is found in many places, (2) carbon moves from place to place, and (3) where it ends up matters. The fact that carbon dioxide is a colorless, odorless gas and essentially “invisible” makes the communication of this message a significant challenge as well as maintaining the students attention. Students cannot “see” carbon in grazing caribou, their breakfast cereal, or a graphite pencil, all seemingly unrelated objects.

I understand what greenhouse gases are.

A.

Pre test: Jul 30



B.

Post test: Aug 12

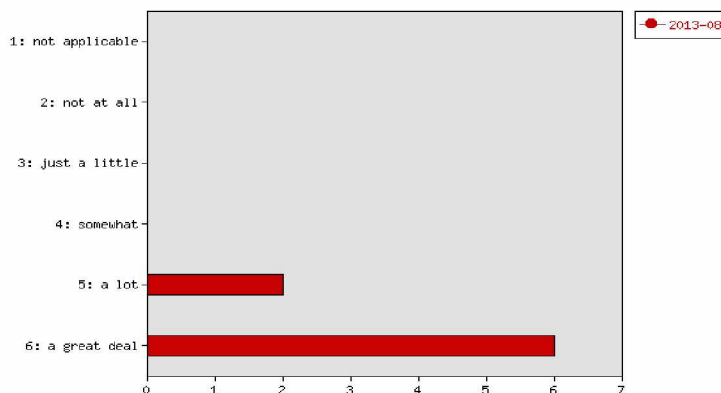
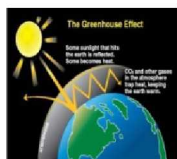


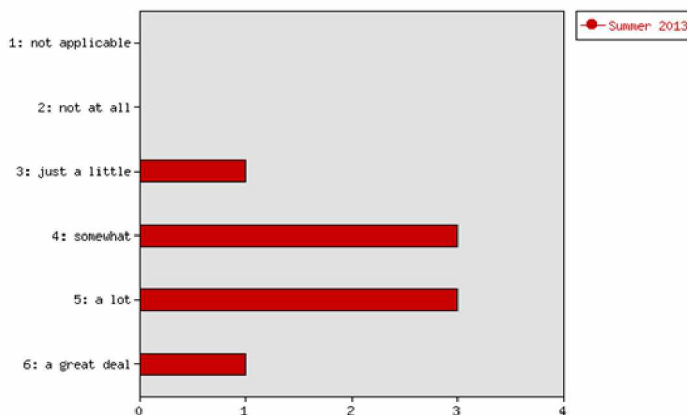
Figure 2.4 Student Assessment and Learning Gains (SALG) results for the question I understand what greenhouse gases are. Pretest and post-test means were significantly different, $p \leq 0.01$

Compounding the issue further is the fact that carbon is found in many chemical forms ranging from methane to crude oil to whale blubber. Students are unable to detect many forms of carbon with their own senses or easily see the impact of these forms on the environment (Figure 2.6).

I understand how topics covered can relate to my village.

A.

Pre Test Jul 30



B.

Post test: Aug 12

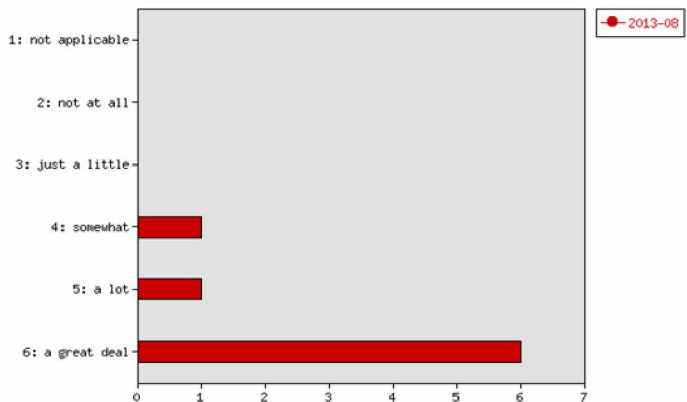


Figure 2.5 Student Assessment and Learning Gains (SALG) results for the question “I understand how topics covered can relate to my village.” Pretest and post-test means were significantly different, $p \leq 0.009$

Instructors carefully assessed students' baseline carbon knowledge and then proceeded to advance it. Interactive activities such as the carbon cycle game included student role playing carbon in different reservoirs (sinks): fossil fuels, atmosphere, or the ocean. A field trip to the Barrow Utilities and Electric Company provided a first-hand look at the carbon-based fuels that are burned to produce energy and transport water for the Barrow community.

Table 2.5 Student presentation titles

Carbon Dioxide
Climate Change Affecting Caribou
Climate Change Affecting Geese
Climate Change on the Sea Ice
Climate Change: Melting Permafrost is Affecting Our Ice Cellars
Global Warming in Alaska: Sea Ice
Global Warming Solutions
How Climate Change Affects Whales
Permafrost and Greenhouse Gases
Temperature Effects
The Difference Between Weather and Climate Change
The Effects of Climate Change on Land and Infrastructure

Kate Cooper, Institute for Computing in Humanities, Arts, and Social Science, assisted students with their public presentation preparations

Capitalizing on the wealth of Barrow's local and visiting scientific knowledge, the instructors invited scientists who spoke about climate change issues that reinforced the fundamental relationship of the carbon cycle to a changing climate. Students learned about changes occurring in weather patterns and their effect on the environment, the arctic wetlands and the millions of migratory birds that visit each summer, human and ecosystem interaction specifically on the tundra, how greenhouse gases are impacting the environment, and the changing permafrost. During fieldtrips, students were exposed to a wide variety of instrumentation, covering remote sensing satellites, time lapse photography, and dynamic soil flux chambers to name only a few (Table 2.6).

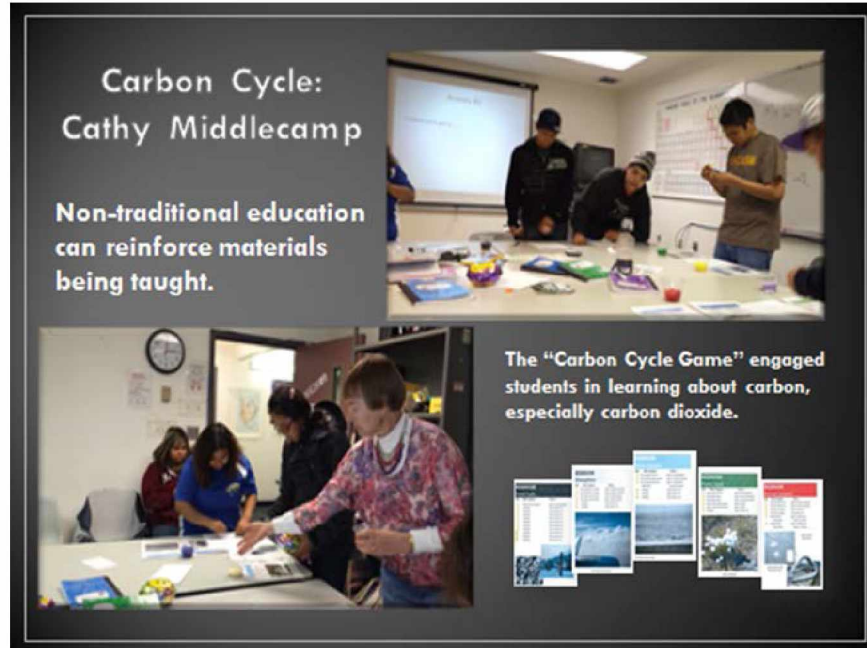


Figure 2.6 Students learned about carbon and then played the *Carbon Cycle Game* reinforcing carbon's movement from air to land to water to plants and animals. Photograph by Linda Nicholas-Figueroa

Of equal importance was the opportunity to spend time with North Slope Elders who spoke of topics related to climate change: economics, storms, sea ice, polar bears, walrus, whales, caribou, ice cellars, invasive species, traditional knowledge and science, and adaptation and policy. For example, Elder Martha Stackhouse spoke about changing plant and animal migration patterns as the climate warms and invasive species are migrating north.

There are more sourdocks than ever, and the pussy willows are taller than they have ever been. Grass niches used to only be inches in diameters are now several feet in diameter. There are many new plants in Barrow; Fireweed now grows in Barrow, when it once did not. Cranberries and Labrador tea are coming further north. The berries (salmonberries and cranberries) are almost to Wainwright. (Martha Stackhouse, personal communication, July 2015).

Table 2.6 North Slope fieldtrip presentations

Scientist	Affiliation	Presentation details
Dr. Bob Rabin	NOAA, National Severe Storms Laboratory	Computer-based activities gave students an opportunity to learn about remote observation, such as satellites, and how they are used in climate research and weather forecasting. Dr. Rabin explained satellite observations of clouds, sea, ice, and land. Students used geostationary satellite and NASA's high resolution imagery for real time weather observations. Students watched annual ice movement from scatterometers (space radar), analyzed snow and ice cover change, interpreted weather forecast models and made their own weather forecasts. The film, <i>Inuit Observations on Climate Change</i> , was shown.
Dr. Christian Andersen	University of Texas at El Paso	Dr. Andersen uses a combination of aquatic ecology and remote sensing to understand long-term changes (biological, hydrological, chemical) in the arctic wetlands. The use of a kite rig and time-lapse photography for monitoring was demonstrated.
Dr. Robert Hollister	Grand Valley State University	Interested in the interactions between humans and natural ecosystems with an emphasis in vegetation change, Dr. Hollister discussed the response of changing tundra to global warming. Dr. Hollister discussed his findings on how climate change is affecting tundra ecosystem land use.
Drs. Eric Wilkman and Katherine McEwing	University of California San Diego University of Sheffield, UK	Drs. Wilkman and McEwing reinforced the importance of understanding the carbon cycle. They provided a context for the roles played by greenhouse gasses, permafrost and microbes and plants in the large scale process and explained how changes in the Arctic affected the global carbon cycle and impacted climate change. They included explanations of methodology and instrumentation that measure trace gas fluxes. Wilkman and McEwing invited the students to the Barrow Environmental Observatory and showed them the instrumentation (eddy covariance towers, dynamic soil flux chambers) in action.

Students were thoroughly engaged during the Elder's visits. They listened intently and asked questions. Students learned from the Elders who shared their own personal experiences through stories while, at the same time, pass on traditional knowledge. As climate is warming fastest in the Arctic, the students often have stories to tell from their own observations.

High school students, especially those from rural areas, rarely have the opportunity to interact with the scientific community. The course design planned on students obtaining information that would lead them to attend a scientific meeting. Three students (two from Wainwright, AK, and one from Shishmaref, AK) attended the Society for the Advancement of Chicanos/Hispanics and Native Americans in Science (SACNAS) National Conference, where

they attended symposiums, leadership development seminars, poster (Figure 2.7), and keynote sessions. Two Barrow students and one student from Point Lay were selected to attend the 18th Inuit Studies Conference in Washington, DC, where they delivered their community presentations on climate change and participated on a youth discussion panel.

Elise Patkotak, reporting for the *Arctic Sounder*, wrote:

Student participant Kenneth Ivanoff told Nicholas-Figueroa, who accompanied the students to Washington, that he was excited about meeting so many people from so many different places in the world. He told her he learned a lot from the sessions he attended and, in particular, enjoyed the plenary speech by Mark Serreze, Director of the National Snow and Ice Data Center. According to Ivanoff, Serreze “talked about things I learned in summer camp about the effects of global warming on sea ice and permafrost in the Arctic.” Mead Treadwell, Alaska’s Lt. Gov., also spoke and discussed “the State’s work addressing cultural challenges, resource development, and environmental change.” As liaison for Alaska to the Arctic Council, he addressed the issues of international geopolitics as it related to the work of the Arctic Council (Patkotak 2013).

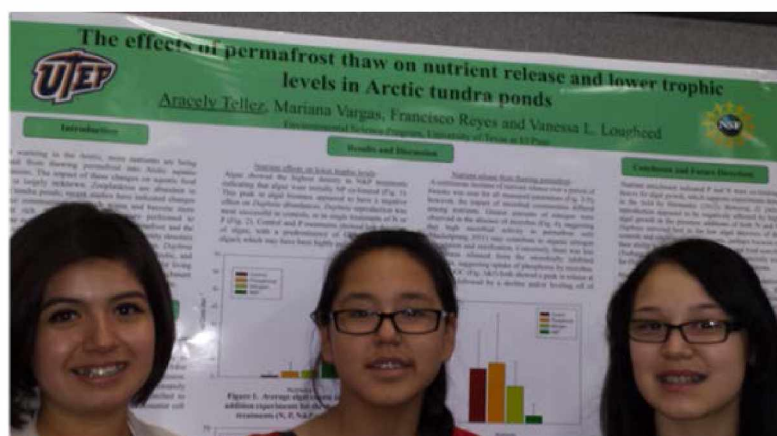


Figure 2.7 Students attending SACNAS poster session. Photograph by Linda Nicholas-Figueroa

2.5 Future efforts

Future effort will be devoted to the development of similar modules focused on TEK and STEM topics associated with community workforce development goals. Iḷisaḡvik College offers STEM science camps for youth on the North Slope to introduce them to research being conducted in their immediate environment. Science curricula in the form of short courses such as biotechnological skills workshop and citizen science projects with the North Slope Borough School District are being developed. Next steps include partnership with UMIAQ Science, a subsidiary of the Ukpeaḡvik Iñupiat Corporation, to create internships for college and high school students to work with local and visiting scientists in Barrow. Climate change is a complex system involving both ecosystem services and human social and political systems. Both the social issues and the science can be used to engage students (Duffy et al. 2011a).

Our goal is to engage students so that they can see STEM's abstract (invisible) concepts in their lives and communities. It is practical to combine the traditional, holistic world view of the community with the reductionist scientific approach. The community's perspective is that "Western science" has much to learn from traditional ecological knowledge (TEK) and its associated values of living on the land. In order to maintain a dynamic culture, it is essential that TEK be a strong component of their children's education for their long-term well-being.

2.6 Conclusion

This summer STEM program is an informal way of engaging students in science concepts while seeing the relevance to real-world issues. Student assessment showed an increase in knowledge to how real-world issues can directly relate to community concerns, such as the local challenges of adapting to a changing climate. By connecting science to region, cultural traditions and values are inserted into the learning experience. This interdisciplinary approach

makes the science, as well as the social, economic, and cultural relationships, visible. Teaching science in a holistic, informal context with both Western and TEK provides a balanced perspective as we educate tomorrow's leaders and decision makers.

Acknowledgements

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References

- Barnhardt R (2005) Culture, community, and place in Alaska Native education. Democracy and education.,
<http://ankn.uaf/Curriculum/Article/RayBarnhardt/CultureCommPlaceANE.html>.
Accessed October 20, 2016
- Department of Energy (2015) Atmospheric radiation measurements: climate research facility.,
<https://www.arm.gov>. Accessed October 26, 2015
- Duffy L, Godduhn A, Fabbri C, van Muelken M, Nicholas-Figueroa L, Middlecamp C (2011a) Engaging students in science courses: lessons of change from the Arctic. *Interchange A Quarterly Review of Education* 42(2):105-139
- Duffy L, Godduhn A, Dunlap K, van Muelken M, Middlecamp C (2011b) Sustainability and chemistry: key concepts in an Arctic focused interdisciplinary course. In: Middlecamp C, Jorgenson A (eds) *Sustainability in the chemistry curriculum*. American Chemical Society Symposium, Washington, 1087:97-112
- EPA (2015) Environmental Protection Agency: Climate Impacts in Alaska.,
<http://www3.epa.gov/climatechange.html>. Accessed October 26, 2015
- Lowan G (2012) Expanding the conversation: further explorations into Indigenous environmental science education theory, research, and practice. *Cultural Studies of Science Education* 7:71-81. doi:10.1007/s11422-012-9379-1
- Mazzocchi F (2006) Western science and traditional knowledge: despite their variations, different forms of knowledge can learn from each other. *EMBO Report. Science and Society viewpoint* 7(5):463-466. doi:10.1038/sj.embor.7400693, PMICD; PMC1479546
- Medin D, Bang M (2014) *Who's asking? Native science, Western science and science education*. MIT Press, Cambridge
- Nakashima D, Roué M (2002) Indigenous knowledge, peoples and sustainable practice. In: Timmerman P (ed) *Encyclopedia of global environmental change. 5: social and economic dimensions of global environmental change*. Wiley, Chichester, pp 314-324
- Nicholas-Figueroa L, Barnhardt R, Duffy L, Dunlap K, Middlecamp C (2015) Delivering post-secondary STEM education on the North Slope, Alaska: resilience and adaptation. *International Research in Education* 3(2):80-92
- NOAA. ESRL. GMD (2015) NOAA Earth System Research Laboratory, Global Monitor Division., www.esrl.noaa.gov/gmd/. Accessed October 26, 2015
- NOAA. NWS (2015) NOAA National Weather Services. Alaska Region Headquarters.,
<http://www.arh.noaa.gov>. Accessed October 26, 2015

- NSB (2016) Official Website of the North Slope Borough,
<http://www.north-slope.org/information/vistors-information>. Accessed May 10, 2016
- Patkotak E (2013) North Slope students travel to D.C. for Inuit Studies Conference, The Arctic Sounder., Retrieved from www.thearcticsounder.com
- Perkins J, Middlecamp C, Blockstein D, Cole J, Knapp R, Saul K, Vincent S (2014) Energy education and the dilemma of mitigating climate change. *Journal Environmental Studies and Sciences* 4:354-359
- SALG (2013) Student Assessment of Learning Gains, <http://www.salgsite.org/instructor/signin>;
<http://www.salgsite.org>. Accessed December 22, 2015
- Seymour E, Weise D, Hunter A, Daffinrud SM (2000) Creating a better mousetrap: on-line assessment of their learning gains., National Meeting of the American Chemical Society,
<http://www.salgsite.org>. Accessed December 23, 2015
- Shepro C (2010) The North Slope Borough Economic Profiles and Census Reports.,
http://www.north-slope.org/departments/mayorsoffice/census_data_2010.php. Accessed January 4, 2014
- Stephens (2000) Handbook for culturally-responsive science curriculum. Alaska Science Consortium and the Alaska Rural Systemic Initiative

Chapter 3

Implementing Indigenous Knowledge in Western Science Education Systems and Research on Alaska's North Slope¹

Abstract

In the last decade, informal and place-based instructions are on the rise in higher educational institutions, of which many programs have shown positive impacts. These impacts include, but are not limited to, the introduction of Native language, Native American art, and how to combine Indigenous knowledge with geological processes. Similarly, methods to incorporate Indigenous knowledge into research practices have been achieved. Examples of introducing research conducted on the North Slope of Alaska into place-based field trips consist of learning the importance of animal migration, whale feeding patterns, chemical composition of air pollution, and significance of sea-ice conditions. These are all important Indigenous community issues that have direct impacts on their culture and ties to the land. Informal education is as simple as allowing Elders to communicate their knowledge to students through classroom visits and participate as instructors. Informal educational practice involves teaching Indigenous students the traditional ways of knowing first and then introducing them to Western science, such as describing the hydrology of an eddy along a river. Indigenous knowledge is explained by defining the pre-Westernization of Indigenous knowledge through story or experience and comparing it to Western knowledge and Western science interpretations.

¹Nicholas-Figueroa, L. Wall, D. van Muelken, M. & Duffy, L. Implementing Indigenous Knowledge in Western Science Education Systems and Research on Alaska's North Slope. Prepared for submission to the *International Journal of Education*. <http://www.macrothink.org/ije>

3.1 Introduction

Tied to cultural and spiritual identity, Indigenous knowledge, also referred to as traditional ecological knowledge (TEK) constantly evolves in tandem with a changing environment and is passed down to the next generation (Bartlett et al., 2012; Cochran, 2013). Worldview, a particular group's perspective and ways of knowing, will vary between cultural groups. Today, this knowledge and the value of worldviews are just as important as the knowledge presented in Western style education. The two systems can co-exist allowing for the Indigenous population to have a better understanding of both worlds (Bartlett et al., 2012). Indigenous knowledge can be woven into Western education, science, and research in a variety of ways using educational approaches that follow an informal approach and place-based settings. Many higher institutions are slowly adopting forms of informal and place-based instruction with positive impacts on the students learning gains (Dubiel et al., 1997; Palmer et al., 2009; Kirby, 2014; Medin & Bang, 2014; Reano and Ridgway, 2015; Van Doren & Duffy, 2016).

3.2 Literature Review

3.2.1 Indigenous Knowledge: Pre-Westernization and Alaska Native Knowledge

Although Alaska Natives have a great variety of cultural traditions, one can also find a number of common features, many of which help to shape their ways of knowing. In 2006 Oscar Kawagley wrote, "Native peoples developed many rituals and ceremonies with respect to motherhood and child rearing, care of animals, hunting and trapping practices, and related ceremonies for maintaining balance between the human, natural, and spiritual realms." Schooling, in essence, involved Elders teaching the youth to maintain balance in their environment (Nicholas-Figueroa et al., 2015).

Males were educated to be active listeners and Elders were the instructors (Jones-Sparck, 2011). They learned about hunting, fishing, how to read the environment, survival and other life skills. Lucy Jones-Sparck (2011) gives this example: “when they dealt with the subject of survival tools, they included the science of nature, how to read the sign about what nature was about to do or just did, and how to respond in respect.” Mothers and Elder women in the community taught young women to spiritually support their husbands when they were out hunting, tending to domestic skills and how to comfort themselves during womanly cycles, pregnancy and child rearing (Kawagley, 2006).

These lessons meet the needs of Alaska Natives and are directly related to their ecological systems (Nelson, 1983); the environment is an integral part of their learning process (Kawagley, 2006) and is tied to Native peoples’ myths, rituals, and ceremonies (Freeman et al., 1988; Locust, 1988; Feinup-Riordan, 1990). The information bestowed comes from the harmony that exists between the natural and spiritual worlds (Kawagley, 2006). Referring to Yup’ik people, Harold Napoleon wrote, “Yuuraraq, the way of the human being, encompassed the spirit world in which the Yup’ik lived. The Yup’ik, the land, rivers, heavens, seas, and all that dwelled within were spirit, and therefore, sacred (Napoleon, 1991).” Beginning in the 18th century, colonization perpetrated by Western societies, upset the natural balance Alaska Natives had with their environment, spiritual direction, and their legacy for subsequent generations. Western educational methods were imposed on Alaska Natives supplanting the traditional ways of learning (Kawagley, 2006).

3.2.2 Indigenous Knowledge and Western Education

Traditional education is holistic and does not essentially separate ecological knowledge, human beings or nature from the world (Cajete & Pueblo, 2010). These ways of knowing are in contrast to Western styles of educational format. In the article, “Culture, Community and the Curriculum” Ray Barnhardt (1981), points out the many different educational and learning approaches for engaging students of Alaska Native and other cultural minorities.

“Minority students residing in their own ethnic communities are raised with their community cultural identities and values. For many peoples, especially American Indians and Alaska Natives, culture is the centerpiece for continued knowledge towards survival. In the past, education was part of everyday activities. The student learned by “doing.” Today students sit long hours in a classroom being talked to with very few options to execute what they supposedly learned. Now, a prime focus is to integrate these teachings into higher educational institutions.”

To overcome this challenge one direction is to convert the usual formal educational format to an informal practice that allows for the beneficial addition of Indigenous knowledge into teaching practices. McGloin et al. (2009) is a strong supporter of encouraging Indigenous peoples to teach their cultural ways of knowing throughout the educational system. The authors further state that Elders and other knowledgeable individuals should be recognized for their cultural knowledge at a level comparable to the Western Doctorate of Philosophy degree, leading to employment as adjuncts or associate positions within the university system. The University of Alaska and Iñisagvik College bestow Honorary Degrees to Alaska Native Elders each year during the commencement ceremony.

Bartlett et al. (2012) describes informal education as a weaving process between Indigenous knowledge systems and mainstream or Western education systems, which involves those holding Indigenous knowledge, such as Elders, along with Western science experts. Two of the authors, Murdena Marshall and Albert Marshall, are aboriginal Elders from the Mi'kmaq Nation in Canada. Elder Albert Marshall defines this as “Two-Eyed Seeing,” a learning process that demonstrates the strengths of Indigenous knowledge (one-eye) and the strengths of Western knowledge (other eye). Together these eyes are advantageous to everyone (Bartlett, 2006; Hatcher et al., 2009; Iwama et al., 2009; Hatcher & Bartlett, 2010; Marshall et al., 2010; Bartlett, 2011, 2012; Bartlett et al., 2012; IISH website, <http://www.integrativescience.ca>). It is important that Indigenous knowledge be recognized as an individual knowledge system standing alongside Western education systems (Iwama et al., 2009; Bartlett et al., 2012). Elder Marshall continues to say that “we need to weave back and forth between our knowledges because in a particular set of circumstances, it may be that one has more applicable strengths than the other, yet with changing circumstances this can easily switch (Bartlett et al., 2012).”

Of equal importance is the understanding that traditional knowledge is always changing. Elder Murdena Marshall states that Indigenous knowledge “was never meant to be static and stay in the past; rather it must be brought into the present so that everything becomes meaningful in our lives and in our communities (Bartlett et al., 2012).” Former Executive Director of the Alaska Native Science Commission and former Chair of the Inuit Circumpolar Council, Iñupiat Elder, Patricia L. Cochran, was interviewed as part of the Wisdom of the Elders radio program regarding the value of traditional knowledge. Elder Cochran told listeners: “Traditional knowledge builds. And that’s what it’s about: it’s just not knowledge from the past; it really builds from what I know today and what generations will teach (Cochran, 2013).”

3.2.3 Strategies for Implementing Indigenous Knowledge in Conjunction with Western Science

Like traditional knowledge, Western science builds from previous knowledge, but is constrained by the boundaries of the Western scientific methodologies. In contrast, traditional knowledge is contingent upon an ever changing world; it is constantly altering and evolving to encounter new and/or unforeseen situations or conditions.

Traditional knowledge is intricately entwined with subsistence activities (Kawagley & Barnhardt, 1998). “Native people know a great deal about the flora and fauna, and they have their own classification systems and versions of meteorology, physics, chemistry, earth science, astronomy, psychology (knowing one’s inner world), and the sacred (Burgess, 1999).” When appropriately woven together, traditional knowledge and Western science can deliver boundless volumes of information that is absent when conveyed only by Western ways.

Kimmerer (2002) discusses how traditional knowledge can be merged with biological sciences, including detailed observations of flora and fauna and their surrounding ecological environment. This knowledge can substantially support scientific hypotheses or redirect scientific research (Kimmerer, 2002). For example, scientists may miss vital information due to short term observation as opposed to years of observation performed by Indigenous peoples who impart knowledge through the generations. This kind of long term exposure to the subject is particularly useful in helping to formulate a hypothesis for study as well as interpreting the results. Where conventional methods of Western science may yield specific quantifiable observations of a given subject, Native voices may be particularly helpful to raise the right questions to begin with, and in helping to relate the findings of particular study to a larger body of practical knowledge. For a specific example, Nakashima (1993) compared collaborative

reports about Hudson Bay eider (*Somateria mollissima sedentaria*) developed between wildlife biologists and Inuit hunters, and he found the Inuit were significantly more knowledgeable than the wildlife biologists, which included eider winter behavior, mortality, and demography. These findings suggest that Western science and Inuit knowledge combined can complement environmental impact assessment studies (Nakashima, 1988). Other instances confirm the strength of Indigenous knowledge indicating an advanced understanding of “fisheries (Berkes, 1977), caribou age structure (Mander, 1991), census of bowhead whales (Huntington et al., 1999), forest fungi (Richards, 1997), wolves (Stephenson, 1982), and food plants (Anderson, 1996; Turner et al., 2000) (Kimmerer, 2002).”

Indigenous knowledge is transmitted through everyday activities such as observation, storytelling, dance, and song. The children or students learn effortlessly from these practices. Kawagley and Barnhardt (1998) describe how these practices can be woven into the Western knowledge system or Western science (or vice versa) using the following example:

“To bring significance to learning in indigenous contexts, the explanations of natural phenomena cast first in Native terms to which students can relate, and then explained in Western terms. For example, when describing an eddy along the river for placing a fishing net, it should be explained initially in the indigenous way of understanding pointing out the currents, the movement of debris and sediment in the water, the likely path of the fish, the condition of the river bank, upstream conditions affecting water levels, the impact of passing boats, etc. Once the students understand the significance of the knowledge being presented, it can then be explained in Western terms, such as flow, velocity, resistance, turbidity, sonar readings, tide tables, etc., to illustrate how the modern explanation adds to the traditional understanding (and vice versa). **All**

learning should start with what the student and community know and are using in everyday life. The Native student will become more motivated to learn when the subject matter is based on something useful and suitable to the livelihood of the community and is presented in a way that reflects the interconnectedness of all things.”

Many post-secondary institutions have successfully engaged Elders in the classroom; have recognized Indigenous knowledge and cultures as part of student learning gains; and support community engaged research and learning approaches. A number of strategies for accomplishing these goals are presented by Knudson (2015): 1) fostering of indigenous knowledge is advantageous in supporting campus growth: physical space, events and curriculum content; 2) student engagement need not be limited to a specific cultural background – involving all cultures will assure a means of knowing in multiple ways; 3) allotted time is essential for instructors to compile materials/resources needed to formulate engaging lessons (Machtmes et al., 2009; Potter, et al., 2003); and 4) hands-on learning is a key component to learning along with realistic projects each focusing on traditional ecological knowledge (Battiste, 1998, Castellano, 2000; Battiste, 2002).

3.2.4 Place-based Education: Geoscience as an Example

The environment or “sense of place” (Semken, 2005; Medin & Bang, 2014; Lowan-Trudeau, 2015) has significant meaning for Indigenous peoples, and it is important to link educational concepts to the physical and cultural landscape (Semken & Morgan, 1997; Kawagley & Barnhardt, 1999; McCarty, 2002). Place-based instruction accomplishes this objective by acknowledging a sense of place, connecting the values of and connections to places that are important to cultural and educational beliefs (Semken, 2005). Western teachings are mostly concentrated in the classroom and rely on textbooks and laboratory simulations; whereas place-

based teachings occur in the field (outdoor environment) or in the community (Semken, 2005).

As the following examples indicate, Geoscience provides an ideal model for place-based instruction; five general guidelines for successful implementation have been distilled (MacIvor, 1995; Lieberman & Hoody, 1998; Kawagley & Barnhardt, 1999; Cajete, 2000; Woodhouse & Knapp, 2000; Gruenewald, 2003; Semken, 2005). While these guidelines are based on teaching American Indian or Alaska Native students, they also suggest implementation strategies for place-based teaching in any context.

- **Content is focused explicitly on the geological and other natural attributes of a place**

Emphasis is placed on the understanding of Earth systems from the perspective of how the physical sciences correlates to the students' surroundings in contrast to learning about other environments detailed in textbooks.

- **Content integrates, or at least acknowledges, the diverse meanings that place holds for the instructor, the students, and the community**

Indigenous knowledge of the surroundings is gathered from the students and community members to include integration of Indigenous language and local place names with Earth science nomenclature. Representations of place in the works of Indigenous or local artists (e.g., Harjo & Strom, 1989) can be incorporated.

- **Content is taught by authentic experiences in that place, or in an environment that strongly evokes that place**

Learning through place-based (field experience) instruction can be powerful.

Supplemental materials such as Indigenous art, images and historical maps of the surroundings enhance the scientific concepts presented.

- **It promotes and supports ecologically - and culturally - sustainable living in that place**

Culturally relevant learning goals incorporate diverse problem-based activities that are tied to the environment, community, and economics.

- **It enriches the sense of place of students and instructor**

Both students and instructors learn and gain knowledge through others (Elders, classmates, colleagues) of the language, land, and cultural ties to the surroundings.

A wide variety of regionally adapted geoscience curricula (classroom and field courses) for Native Americans and First Nations peoples bridge the gap between Indigenous groups, scientists, and educators (Riggs, 2004). For instance, Dine' College developed an integrated Earth science curriculum (Dubiel et al., 1997) incorporating the Navajo language and traditional knowledge into the major themes that directly related to the Navajo's understanding of the natural world (Riggs, 2004).

In an undergraduate geoscience course 'Earth Systems on the Southern Great Plains,' Palmer et al., (2009) used a multidisciplinary approach with a global perspective emphasizing the southern plains, particularly Oklahoma's "sense of place." Indigenous philosophies, traditional stories, metaphors, and Native American art were integrated into the geoscience content with resounding success.

Reano and Ridgway (2015) discuss how a geological discipline, such as stratigraphy, has cultural relevance to the Native American community of Acoma Pueblo, New Mexico: Geologists use stratigraphic nomenclature to describe the Earth's physical features, identifiable patterns and depositional environments while the Acoma Pueblo community members' describe the same stratigraphic intervals in terms of cultural uses, such as in making pottery, building

their homes out of rock and mud, and farming the land. Using both the Western geological analysis alongside the Acoma Pueblo's cultural description produces a greater understanding of the concepts involved. For example, the use of Dakota Sandstone as building material becomes clearer when presented from both the cultural and scientific perspective. They further suggest that science, technology, engineering, and mathematics (STEM) education for diverse students is partially dependent on the community's strength of knowledge regarding landscape uses, natural resources, geoengineering, climate change, and other aspects of earth science (Reano & Ridgway, 2015).

Typically, introductory geoscience courses are designed for students pursuing a geoscience degree or other physical science major degree. Kent Kirby (2014), University of Minnesota, designed entry-level geoscience laboratory modules using a place-based approach: Using the region's cultural heritage from the 18th century to modern day, Kirby explored Dakota, Ojibwe and Euro-American perspectives. The "Upper Mid-west's Glacial Legacy" laboratory module asked students to explore the glacial system's importance to the present landscape, ecosystems, and human history. For example, students learned how the different cultural uses of the region's diverse resources evolved over time: how woodlands and prairie became "timber" and "acreage." Using the same place-based and historical approach, the collection of laboratory modules provided a way for students to learn about specific geological processes. Equally important, the students' explorations of these geological processes demonstrated their cultural ties to the land (Kirby, 2014).

Nicholas-Figueroa, et al. (2016) demonstrated that teaching STEM concepts through informal and place-based learning is accomplished with lessons provided by educators, scientists, and local Elders in their summer program, *Climate and Permafrost Changes on the*

North Slope: In Cultural Context held in Barrow, AK for middle school and high school students. Educators introduced the relationship of the carbon cycle to a changing climate. Scientists reinforced these lessons through topics on weather patterns, the arctic wetlands, bird migration, human and ecosystem interactions specifically on the tundra, impacts of greenhouse gasses on the environment and the changing permafrost. Elders spoke on topics related to climate change and important issues that are most relevant to the students' communities and environment: economics, storms, sea ice, polar bears, walrus, whales, caribou, ice cellars, invasive species, traditional knowledge and science, and adaptation and policy.

3.3 Implementing Educational use of Indigenous Knowledge into Informal Education and Research Practices in a Northern Alaska Community.

Often middle and high school students' first interest in STEM coincides with exposure to informal learning in the structure of a science project that is to be presented to the class or at a science fair as demonstrated by the Alaskan Partners in Science Program. Students are allowed to select and design their own projects with the assistance of parents, or in some cases, college students and scientists. Incorporation of an indigenous portion to the project by integrating culture and values can add further depth and meaning to the science project. It also creates greater engagement for students who have difficulties with abstract concepts. For example, a student may be interested in the traditional uses of whale oil (a familiar entity), in which the topic of combustion would constitute the science. During the science fairs judging process, local Elders can be added to the judging team to score the traditional knowledge and how it adds value to the project.

From an environmental science perspective, strategies for overcoming cultural barriers between scientists and rural communities should include methods to work directly with the communities. The framework suggested by Semken was used with modifications by Nicholas-Figueroa and Wall. Researchers should be encouraged to consider community concerns and strive to build collaborative relationships. Recommendations from our experience include:

- Seek expert advice from Elders prior to beginning the research. Traditional knowledge is passed down through the generations; therefore, Elders have much to contribute throughout the research process. Recognize that not all Elders are experts in every topic. Ask community members for assistance about whom to best approach the needs of the research. *“Research that bridges the gap between local knowledge and science can provide reciprocal benefits to scientists and local communities (Huntington, 2000; Carmack and Macdonald, 2008; Weatherhead et al., 2010; Huntington et al., 2011) (Jones, et al., 2015).”*
- Recruit additional research team members such as local students who can create interest and contribute local knowledge. Traditional knowledge is not limited to Elders and researchers may choose to recruit other Indigenous participants. For example, if investigating the decline of Arctic caribou, it would be wise to recruit local hunters to elicit their observations and discuss their thoughts on the reasons for these changes. Local hunters can provide expertise and may be willing to assist with sample collections. *“Traditional knowledge and local observations have been used in conjunction with scientific methods to gain a better understanding of how rural people rely on physical and natural phenomena (Krupnik and Jolly, 2002; Chapin et*

al., 2006; Carmack and Macdonald, 2008; Pearce et al., 2009; Weatherhead et al., 2010; Druckenmiller et al., 2013; Eicken et al., 2014) (Jones et al., 2015)."

- Share the research ideas and goals with the community before beginning a new project and provide periodic updates (especially when there are significant findings) if project is long term. Informal presentations with question and answer sessions between community members and researchers are an effective means of communication. Refreshments or a community meal are always welcome. The kind of hospitality reflected in the offering of a meal does more in fact than to set a friendly tone; it may in effect help to transform the setting in which conclusions are to be presented into something more familiar to the Indigenous context in which such information would normally be shared. Specific cultural practices may also play a role here. Where appropriate, gift exchanges and/or local conventions of address, seating, and personal conduct should be considered. *"A desirable research objective would aim to produce tools or other research products that will also benefit local collaborators (Nadasdy, 1999; Cruikshank, 2001) (Jones et al., 2015)."*
- Outreach presentations to middle/high school students, including opportunities for field visits, are encouraged. Students are rarely introduced to research practices even those carried out in their own communities.

By engaging in dialogue with Indigenous communities, researchers help to provide them with a stake in their projects, and the knowledge coming from it. Indigenous sources can thereby help to comment on results and suggest ideas for future study. Having been informed about the

conclusions of a study, they may also become (at their own discretion) agents in the promotion of a study. If Indigenous people find value in a research project, they may themselves take a role in communicating its results to others.

3.4 Introducing TEK and Research Conducted on the North Slope of Alaska into Place-Based Education

Alaska's North Slope Borough (NSB), 300 miles above the Arctic Circle, is home to a copious and diverse collection of marine mammals, fish, plants, and wildlife (Streever et al., 2011) and home to ~10,000 Iñupiat people. Having experienced an average 3 °Fahrenheit temperature increase over the past 60 years (EPA, 2015) the North Slope is on the forefront of environmental and ecological change. These resultant changes are a focus of scientific research, often occurring in the eight local villages or communities of the NSB, which are only accessible by airplane.

While there is an abundance of scientific research conducted on the North Slope of Alaska, students are rarely exposed to the findings of these research endeavors, especially those related to their communities. Using a place-based setting and including exposure to the scientific community, Elders' Indigenous knowledge, and tapping students' traditional ecological knowledge adds significant value to the understanding of STEM subjects. Scientific techniques can be taught within a relevant setting or culturally germane lab.

Using ecology and the Glaucous gull as an illustration, students can learn how a warming climate can impact the food chain and the local ecological balance. Hunted by humans for both meat and eggs, the Glaucous gull is a fierce predator consuming eggs, chicks, small mammals and fish, all part of the community's subsistence diet. One approach to a balanced lesson would

include a discussion between Elders and local hunters describing their observations regarding changing movement patterns. Researchers could provide gull flight data (Figure 3.1). Students could be trained as recorders (gull movement, Elder/hunter knowledge, other data) and theorize how changes in these patterns could impact the local environment. The preparation of a scientific poster from the obtained data would further enhance the experience.

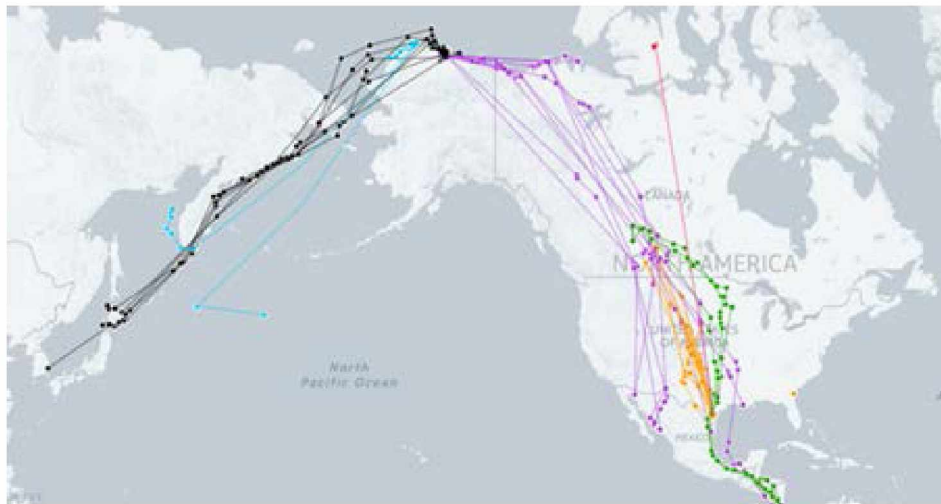


Figure 3.1 Migration of a Glaucous Gull from Barrow, Alaska (blue line). “A Glaucous Gull transmitter woke up this morning and pinged from the southern Kamchatka Peninsula, Russia. This is the bird’s first winter and first migration, and I totally didn’t expect a juvenile bird to go there! The bird traveled over 1,800 miles (Autumn-Lynn Harrison, March 4, 2016; Smithsonian Conservation Biology Institute, Migratory Bird Center).” (www.migratoryconnectivityproject.org/livetracks)

The Bowhead whale, a major dietary food source and symbol of Iñupiat spiritual and cultural identity, provides another concrete example of how place-based instruction augments student learning. For the biology student, Craig George of the North Slope Borough Department of Wildlife Management (NSB-DWM) discuss the concept of Bowhead basic “energetics” or food requirements that can be tied to the understanding of summer and winter feeding areas (personal communication, October 2013). One fairly simple method for estimating energy or food requirements is the “lung volume/respiration rate” method as described by Andreas

Fahlman, Texas A&M University (personal communication, October 2013). During whaling season, NSB-DWM employees obtain organs from harvested whales. Students can visit their laboratory and observe biological studies such as the lung volume/respiration rate study (Figure 3.2). Given known lung/volume respiration rate values of the Bowhead whale, students can analyze the results to determine the Bowhead food requirements.



Figure 3.2 Student observations of the inflation of a Bowhead whale lung. Photo taken by Linda Nicholas-Figueroa.

A chemical science lesson plan includes the understanding of real time sizing, the chemical composition of individual aerosol particles, and the method for determining how these particles impact the Arctic environment. Basic atmospheric chemistry concepts can be explained using an example of how pollutants, such as black carbon, travel from industrialized countries to the Arctic. Concepts can be reinforced by a field trip to see the Aerosol Time-Flight Mass Spectrometer (Figure 3.3). An Elder can either accompany the class on a field trip or visit the classroom to discuss environmental changes he or she has observed as a result of atmospheric pollution. Ideally this can be an interactive dialog between the students, research scientists, and

Elders. As always, students can be encouraged to ask questions and/or discuss their concerns. Students could be asked to write an essay of what they have learned and be tasked with proposing possible solutions.

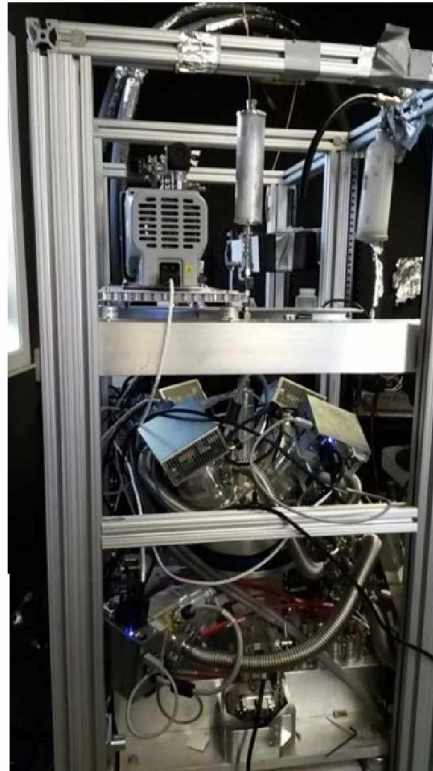


Figure 3.3 Aerosol Time-of-Flight Mass Spectrometer real time sizing and chemical composition of individual aerosol particles. Allows usage of “chemical fingerprints” to identify each particle type.

Photo taken by Linda Nicholas-Figueroa

The Indigenous observations of sea ice provide numerous scientific lessons that relate directly to an individual’s health and safety. Webster and Zibell in the Iñupiat Eskimo Dictionary (1970) list 28 words that define ice. Table 3.1 lists a few of these Iñupiaq words to include sea ice definitions or descriptions that assist a hunter’s evaluation of ice conditions and the implications for safety as well as changing conditions - both of which affect the hunter’s ability to exploit resources in this dynamic setting. Figure 3.4 presents these definitions in an illustrated manner that portrays the significance of understanding the words.

David “Masaq” Leavitt, Jr. describes the importance of paying attention to wind and sea current changes, “shifts in the wind and sea currents are particularly critical insofar as they indicate the likelihood that ice will soon break up” (personal communication, October 2016). Determining the differences between shorefast ice, that which is anchored to the ground below and that which is essentially floating on open sea (ice floes) provides another critical tool for survival on the ice. Elders commonly assess ice conditions with a degree of nuance difficult to capture in discrete scientific observations.

Table 3.1 Some English translations for Iñupiaq terms for sea ice and sea ice formations 653.1 Some English translations for Iñupiaq terms for sea ice and sea ice formations

Iñupiaq	English Translation
Siku	Sea ice
Sikuliirak	Ice thick enough to walk on
Sikulikiruk	Ice is in the process of break-up
Aunnik	Rotten ice (unsafe)
Tuvak	Landlocked Ice; Shorefast ice
Kisisak	Grounded ice pile (keeps landlocked ice from floating away), ice floes
Iyunik	Ice pressure ridge
Puktaak	Iceberg
Sarri	Ice pack
Uinik	Lead (open water between landlocked ice and pack ice)

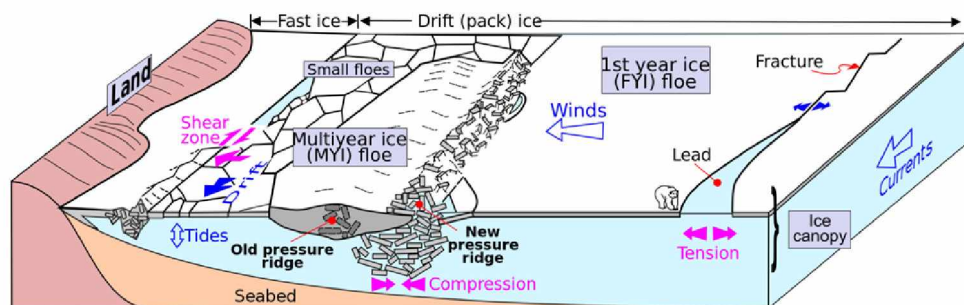


Figure 3.4 Hypothetical sea ice dynamics scenario showing some of the most common sea ice features.
https://en.wikipedia.org/wiki/Sea_ice

3.5 Conclusion

Community members of the North Slope Borough, Alaska are observing changes regarding health, food security, land stability, and how these factors impact cultural practices. The utilization and integration of students' personal knowledge, the knowledge of their Elders and scientific field research creates a powerful means of engaging students in science, technology, engineering, and mathematics (STEM) curricula. Information exchanged in a respectful place-based, culturally relevant setting benefits all involved. Alaska's North Slope provides the ideal place-based laboratory to develop innovative STEM curricula and solutions to the pressing problems such as those resulting from a changing climate.

References

- Anderson, M. (1996). Tending the Wilderness. Restoration and Management Notes. Ecological Restoration. 14 (2), 154-166. doi:10.3368/er.14.2.154. In Kimmerer, R. (2002). Weaving Traditional Ecological Knowledge into Biological Education: A Call to Action. *BioScience*. 52(5). 432-438.
- Barnhardt, R. (1981). Culture, Community and the Curriculum. Retrieved from <http://www.ankn.uaf.edu/curriculum/Articles/RayBarnhardt/CCC.html>
- Bartlett, C. (2006). Knowledge Inclusivity: “Two-Eyed Seeing” for Science for the 21st Century. In Wiber, M., & Kearney, J. (Eds.). (4-5 November, 2005). Proceedings from the Workshop: *Learning Communities as a Tool for Resource Management*. (pp. 70-76). Halifax, Nova Scotia.
- Bartlett, C. (2011). Integrative Science / Toqwa’tu’kl Kjjijitaqnn: The Story of our Journey in Bringing Together Indigenous and Western Scientific Knowledges. In Bernard, T. Rosenmeier, L.M. & Farrell, S.L. (Eds.), Proceedings of the 2005 Debert Research Workshop. *Ta’n Wetapeksi’k: Understanding From Where We Come* (pp. 179-186). Debert, Nova Scotia, Canada, Eastern Woodland Print Communications, Truro.
- Bartlett, C. (2012). The Gift of Multiple Perspectives in Scholarship/Integrative Science. “In My Opinion” in University Affairs. 53(3). 41.
- Bartlett, C. Marshall, M. Marshall, A. & Iwama, M. (2012). Integrative Science and Two-Eyed Seeing: Enriching the Discussion Framework for Healthy Communities. In Hallstrom, L. Guehlstorf, & N. Parkes, M. (Eds.), *Beyond Intractability: Convergence and Opportunity at the Interface of Environmental, Health and Social Issues*. UBC Press, Vancouver.
- Battiste, M. (1998). Enabling the Autumn Seed: Toward a Decolonized Approach to Aboriginal Knowledge, Language, and Education. *Canadian Journal of Native Education*. 22. 16-27.
- Battiste, M. (2002). Indigenous knowledge and Pedagogy in First Nations Education: A Literature Review with Recommendations. Prepared for the National Working Group on Education and the Minister of Indian Affairs. Ottawa: Indian and Northern Affairs Canada.
- Berkes, F. (1977). Fishery Resource use in a Subarctic Indian Community. *Human Ecology*. 5. 289-307.
- Burgess, P. (1999). Traditional Knowledge: A Report Prepared for the Arctic Council Indigenous Peoples' Secretariat. Copenhagen: Indigenous Peoples' Secretariat Arctic Council.
- Cajete, G. (2000). *Native Science: Natural Laws of Interdependence*, Santa Fé, New Mexico. Clear Light Publishers. p. 315.

- Cajete, G. & Pueblo, S. (2010). Contemporary Indigenous Education: A Nature-Centered American Indian Philosophy for the 21st Century World. *Futures*. 42(10). 1126-32
- Carmack, E. & Macdonald, R. (2008). Water and Ice-Related Phenomena in the Coastal Region of the Beaufort Sea: Some Parallels between Native Experience and Western Science. *Arctic*. 61. 265-280.
- Castellano, M. (2000). Updating Aboriginal Traditions of Knowledge. In Dei, G. Hall, B. & Rosenberg, D. (Eds). *Indigenous Knowledges in Global Contexts: Multiple Readings of our World* (pp. 21-36). Toronto. University of Toronto Press.
- Chapin, F. III. Robards, M. Huntington, H. Johnstone, J. Trainor, S. Kofinas, G. Ruess, R. Fresco, N. Natcher, D. & Naylor, R. (2006). Directional Changes in Ecological Communities and Social-ecological Systems: a Framework for Prediction Based on Alaskan Examples. *American Naturalist*. 168(S6). S36-S49.
- Cochran, P. (2013). Wisdom of the Elders Radio Program S4E1. Wisdom of the Elders, Inc.
- Cruikshank, J. (2001). Glaciers and Climate Change: Perspectives from Oral Tradition. *Arctic* 54. 377-393.
- Druckenmiller, M. Eicken, H. George, J. & Brower, L. (2013). Trails to the Whale: Reflections of Change and Choice on an Iñupiat Icescape at Barrow, Alaska. *Polar Geography*. 36(1-2). 5-29.
- Dubiel, R. F. Hasiotis, S. T. & Semken, S. C. (1997). Hands-on geology for Navajo Nation teachers. *Journal of Geoscience Education*. 45(2). 113-116.
- Eicken, H. Kaufman, M. Krupnik, I. Pulsifer, P. Apangalook, L. Apangalook, P. Weyapuk, W. Jr. & Leavitt, J. (2014). A Framework and Database for Community Sea Ice Observations in a Changing Arctic: an Alaskan Prototype for Multiple Users. *Polar Geography*. 37(1). 5-27.
- EPA. (2015). Environmental Protection Agency: Climate Impacts in Alaska. Retrieved From: <http://www3.epa.gov/climatechange.html>.
- Feinup-Riordan, A. (1990). Eskimo Essays: Yup'ik Lives and How We See Them. Rutgers University Press, New Brunswick, NJ.
- Freeman, M. Milton, M. & Carbyn, L. (1988). Traditional Knowledge and Renewable Resource Mangement in Northern Regions. Edmonton: IUCN Commission on Ecology and the Boreal Institute for Northern Studies.
- Gruenewald, D. (2003). Foundations of Place: A Multidisciplinary Framework for Place-Conscious Education. *American Educational Research Journal*. 40. 619-654.

- Harjo, J. & Strom, S. (1989). *Secrets from the Center of the World*, Tucson, University of Arizona Press, p. 67.
- Hatcher, A. Bartlett, C. Marshall, A. & Marshall, M. (2009). Two-Eyed Seeing in the Classroom Environment: Concepts, Approach and Challenges. *Canadian Journal of Science Math Technology Education*. 9(3). 141–153.
- Hatcher, A. & Bartlett, C. (2010). Two-Eyed Seeing; Building Cultural Bridges for Aboriginal Students. Canadian Teacher Magazine. May p. 14–17.
- Huntington, H. and the Communities of Buckland, Elim, Koyuk, Point Lay and Shatoolik. (1999). Traditional Knowledge of the Ecology of Beluga Whales (*Delphinapterus leucas*) in the Eastern Chukchi and Northern Bering Seas, Alaska. *Arctic*. 52. 49–61.
- Huntington, H. (2000). Using Traditional Ecological Knowledge in Science: Method and Applications. *Ecological Applications*. 10. 1270-1274.
- Huntington, H. Gearheard, S. Mahoney, A. & Salomon, A. (2011). Integrating Traditional and Scientific Knowledge through Collaborative Natural Science Field Research: Identifying Elements for Success. *Arctic* 64. 437-445.
- IISH website, <http://www.integrativescience.ca>
- Iwama, M. Marshall, M. Marshall, A. & Bartlett, C. (2009). Two-Eyed Seeing and the Language of Healing in Community-based Research. *Canadian Journal Native Education* 32. 3-23.
- Jones, C. Kielland, K. Hinzman, L. & Schneider, W. (2015). Integrating Local Knowledge and Science: Economic Consequences of Driftwood Harvest in a Changing Climate. *Ecology and Society* 20(1). 25
- Jones-Sparck, L. (2011). Effects of Modernization on the Cup'ik of Alaska. In Ray Barnhardt & Angayuqaq Oscar Kawagley (Eds). *Alaska Native Education*. Chicago, IL, University of Chicago Press..
- Kawagley, A. O. (2006). *A Yupiaq Worldview: A Pathway to Ecology and Spirit*. Waveland Press, Inc. Long Grove, IL. P. 8-18.
- Kawagley, A.O. & Barnhardt, R. (1998). Education Indigenous to Place: Western Science Meets Native Reality. Alaska Native Knowledge Network. Retrieved from <http://ankn.uaf.edu/curriculum/Articles/BarnhardtKawagley/EIP.html>
- Kawagley, A.O. & Barnhardt, R. (1999). Education Indigenous to Place: Western Science Meets Native Reality, In Smith, G.A. & Williams, D.R. (Eds.), *Ecological Education in Action: on Weaving Education, Culture, and the Environment* (pp. 117-140), Albany, State University of New York Press.

- Kimmerer, R. (2002). Weaving Traditional Ecological Knowledge into Biological Education: A Call to Action. *BioScience*. 52(5). 432-438.
- Kirby, K. (2014). Place in the City: Place-Based Learning in a Large Urban Undergraduate Geoscience Program. *Journal of Geoscience Education*. 62. 177-186.
- Knudson, S. (2015). Integrating the Self and the Spirit: Strategies for Aligning Qualitative Research Teaching with Indigenous Methods, Methodologies, and Epistemology. *Forum: Qualitative Social Research*. 16(3). Article 4.
- Krupnik, I. & Jolly, D. editors. (2002). The Earth is Faster Now: Indigenous Observations of Arctic Environmental Change. Arctic Research Consortium of the United States, Fairbanks, Alaska, USA.
- Lieberman, G. & Hoody, L. (1998). Closing the Achievement Gap: Using the Environment as an Integrating Context for Learning, San Diego, California, State Education and Environment Roundtable. p. 106.
- Locust, C. (1988). Wounding the Spirit: Discrimination and Traditional American Indian Belief Systems. *Harvard Educational Review* 58. 315-331.
- Lowan-Trudeau, G. (2015). Contemporary Studies in Environmental and Indigenous Pedagogies: A Curricula of Stories and Place. *Environmental Education Research*. 21(4). 652-653.
- Machtmes, K. Johnson, E. Fox, J. Burke, M. Harper, J. Arcemont, L. Hebert, L. Tarifa, T. Brooks, R. Reynaud, A. Deggs, D. Matzke, B. & Aguirre, R. (2009). Teaching Qualitative Research Methods through Service-Learning. *The Qualitative Report*. 14. 155-164.
- MacIvor, M. (1995). Redefining Science Education for Aboriginal Students. In: Battiste, M.A. & Barman, J. (Eds.), *First Nations Education in Canada: The Circle Unfolds* (pp. 73-98), Vancouver, University of British Columbia Press.
- Mander, J. (1991). *In the Absence of the Sacred: The Failure of Technology and the Survival of the Indian Nations*. (pp. 258). San Francisco: Sierra Club Books.
- Marshall, A. Marshall, M. & Iwama, M. (2010). Approaching Mi'kmaq Teachings on the Connectiveness of Humans and Nature. In: Bondrup- Nielsen, S., Beazley, K., Bissix, G., Colville, D., Flemming, S., Herman, T., McPherson, M., Mockford, S., O'Grady, S. (Eds.). *Ecosystem Based Management: Beyond Boundaries*. Proceedings of the Sixth International Conference of Science and the Management of Protected Areas, 21-26 May 2007. Acadia University, Wolfville, Science and Management of Protected Areas Association, Wolfville, NS.
- McCarty, T. (2002). A Place to Be Navajo-Rough Rock and the Struggle for Self-Determination in Indigenous Schooling. Mahwah, NJ: Lawrence Erlbaum.

- McGloin, C. Marshall, A. & Adams, M. (2009). Leading the Way: Indigenous Knowledge and Collaboration at the Woolyungah Indigenous Centre. *Journal of University Teaching & Learning Practice*. 6(2). Article 4.
- Medin, D. & Bang, M. (2014). Who's Asking? Native Science, Western Science and Science Education. MIT Press, Cambridge, MA.
- Nadasdy, P. (1999). The Politics of TEK: Power and the Integration of Knowledge. *Arctic Anthropology*. 36: 1-18.
- Nakashima, D. (1988). Eider Ecology from Inuit Hunters. In Nakashima, D. & Murray, D. (Eds.), *The Common Eider of Eastern Hudson Bay: A Survey of Nest Colonies and Inuit Ecological Knowledge*. Ottawa: Environmental Studies Revolving Fund Report No. 102.
- Nakashima, D. (1993). Astute Observers on the Sea Ice Edge: Inuit Knowledge as a Basis for Arctic Comanagement. In: Inglis JT, (Ed.) *Traditional Ecological Knowledge: Concepts and Cases*. Ottawa: Canadian Museum of Nature and International Development Research Centre. p. 99-110
- Napoleon, H. (1991). *Yuuyaraq: The Way of the Human Being*. Eric Madsen-Fairbanks (Ed.): Center for Cross-cultural Studies, University of Alaska Fairbanks.
- Nelson, R. (1983). *Make Prayers to the Raven*. University of Chicago Press. Chicago, IL.
- Nicholas-Figueroa, L. Barnhardt, R. Duffy, K. Dunlap, K. van Muelken, M. & Middlecamp, C. (2015). Delivering Post-Secondary STEM Education on the North Slope, Alaska: Resilience and Adaption. *International Research in Education*. 3(2), 80-92. doi: 10.5296/ire.v3i2.7555
- Nicholas-Figueroa, L. Hare, R. van Muelken, M. Duffy, L. & Middlecamp, C. (2016). Iḷisaḡvik Tribal College summer climate program: teaching STEM concepts to North Slope Alaska high-school and middle-school student. *Journal of Environmental Studies and Science*. p. 1-10. Retrieved from <http://link.springer.com/article/10.1007/s13412-016-0413-6>.
- Palmer, H. Douglas, E. Watson, M. Kloesel, K. & Palmer, K. (2009). Xoa:dau to Maunkaui: Integrating Indigenous Knowledge into an Undergraduate Earth Systems Science Course. *Journal of Geoscience Education*. 57(2): 137-144
- Pearce, T. Ford, J. Laidler, G. Smit, B. Duerden, F. Allarut, M. Andrachuk, M. Baryluk, S. Dialla, A. Elee, P. Goose, A. Ikummaq, T. Joamie, E. Kataoyak, F. Loring, E. Meakin, S. Nickels, S. Shappa, K. Shirley, J. & Wandel, J. (2009). Community Collaboration and Climate Change Research in the Canadian Arctic. *Polar Research* 28. 10-27.
- Potter, S. Caffrey, E. & Plante, E. (2003). Integrating Service Learning into the Research Methods Course. *Teaching Sociology*. 31. 38-48.

- Reano, D. & Ridgway, K. (2015). Place in the City: Place-Based Learning in a Large Urban Undergraduate Geoscience Program. *Geological Society of America Today*. 25(8). doi: 10.1130/GSAT-G235GW.1.
- Richards, R. (1997). What the Natives Know: Wild Mushrooms and Forest Health. *Journal of Forestry* (September). 5-10.
- Riggs, E.M., (2004) “Fostering Indigenous Earth Science: Increasing Native American Participation in the Earth Science Enterprise” invited abstract for the 2004 Fall meeting of the American Geophysical Union, special session on “Diversity and Equity in the Earth and Space Sciences: 1. Global Perspectives on the Issues and Obstacles”
- Semken, S. (2005). Sense of Place and Place-based Introductory Geoscience Teaching for American Indian and Alaska Native Undergraduates. *Journal of Geoscience Education*. 53. 149-157.
- Semken, S. & Morgan, F. (1997). Navajo Pedagogy and Earth systems. *Journal of Geoscience Education* 45(1), 109-112.
- Stephenson, R. (1982). Nunamiut Eskimos, Wildlife Biologists, and Wolves. In Harrington, F.H. Pacquet, P.C. (Eds.), *Wolves of the World*. (pp. 434-439). Park Ridge (NJ): Noyes.
- Streever, B. Suydam, R. Payne, J. Shuchman, R. Angliss, R. Balogh, G. Brown, J. Grunblatt, J. Guyer, S. Kane, D. Kelley, J. Kofinas, G. Lassuy, D. Loya, W. Martin, P. Moore, S. Pegau, W. Rea, C. Reed, D. Sformo, T. Sturm, M. Taylor, J. Viavant, T. Williams, D. & Yokel, D. (2011). Environmental Change and Potential Impacts: Applied Research Priorities for Alaska’s North Slope. *Arctic*. 63(3).
- Turner, N. Ignace, M. & Ignace, R. (2000). Traditional Ecological Knowledge and Wisdom of Aboriginal Peoples in British Columbia. *Ecological Applications*. 10. 1275–1287.
- Van Doren, G. & Duffy, L. (2016). Teaching Chemistry in Rural America: A Comparative Study Examining Innovative Informal Education and Applied Science Approaches to Improving Engagement. *International Research in Education*. 4(2).
- Weatherhead, E. Gearheard, S. & Barry, R. (2010). Changes in Weather Persistence: Insight from Inuit Knowledge. *Global Environmental Change*. 20. 523-528.
- Webster, D. & Zibell, W. (1970). Inupiat Eskimo Dictionary. 1970 Summer Institute of Linguistics, Inc. Box 1028. Fairbanks, AK 99701. Library of Congress Catalog Card No. 76-632478. p. 108-109. Retrieved from: library.alaska.gov/hist/hist_docs/docs/anlm/200078.pdf
- Woodhouse, J., & Knapp, C. (2000). Place-Based Curriculum and Instruction: Outdoor and Environment Education Approaches. *ERIC Digest*. Retrieved from <https://eric.ed.gov>

General Conclusion and Future Directions

Science, technology, engineering, and mathematics (STEM) curricula can be taught in ways that integrates Western science and traditional ecological knowledge (TEK) or Indigenous knowledge. Iñupiat Elders can accompany a class on place-based field trips or visit the classroom. In an informal setting Indigenous knowledge, explained through story and observations, is introduced first in Native terms in ways students can relate, then the Western science is introduced (Kawagley & Barnhardt, 1998).

Students are engaged learning important real world issues that are relevant to their local surroundings in a cultural context. Introduction of STEM concepts into these real world issues can be accomplished in many ways to include the significance of understanding climate science in a changing Arctic environment. For example, understanding the carbon cycle and its impact on climate change was an important lesson introduced in the Iḷisaḡvik College summer science program, *Climate and Permafrost Changes on the North Slope in Cultural Context*, for Alaska Native youth (Nicholas-Figueroa et al., 2016).

The Student Learning and Assessment Gains tool demonstrated that students had an increase in knowledge in the science concepts and their understanding of real world issues related to their communities after a short science camp (Nicholas-Figueroa et. al., 2016). Traditional ecological knowledge incorporated into informal and place-based learning can facilitate the students' confidence in making informed decisions and becoming active members within their communities.

The uniqueness of the North Slope landscape, environment, animal diversity, and changes in the climate provide an extensive resource to introduce science, technology, engineering, and mathematic concepts into programs that are culturally relevant. Iḷisaḡvik College provides programs that meet the needs of STEM education and the needs of the North

Slope workforce. These programs can be in the form of short courses, such as weekend workshops or summer camps, and, of course, traditional college curriculum.

Weekend workshops for high school and middle school students can introduce them to STEM fields and prepare them for college science courses. Located 500 miles from the closest higher educational institution and being only accessible by plane, Iḷisaḡvik College is partnered with the University of Alaska Fairbanks Biomedical Learning and Student Training program (BLaST). The BLaST program allows guest scientists to travel to Iḷisaḡvik College to facilitate workshops, such as plant chemistry. New workshops should feature the students learning laboratory techniques that determine the types of microorganisms growing on subsistence meats stored in thawing ice-cellars due to melting permafrost, an important issue to the community. More workshops that combine TEK with discovery and basic science concepts should be developed. Future STEM summer camps should include continuation of the climate change program with an emphasis of studying Arctic microorganisms in the tundra as the climate warms. Introduction of invasive species to the vegetative layer of the tundra could potentially be pathogenic, which can have impacts on subsistence gathering of wild plants, berries, or food for wildlife, such as caribou that feed on lichen.

Partnering with wildlife biologists from the North Slope Borough Wildlife Biology Department students can assist in determining and monitoring the impacts climate change has on land and marine animal health and migration patterns, as well as working with researchers from the University of Alaska Fairbanks on community concerns related to food contaminants, such as mercury. Internships for students to work with local and visiting scientists should be established in collaboration with UIC Science, a subsidiary of Ukpeaḡvik Iñupiat Corporation of Barrow, Alaska.

All of these programs should include informal, place-based, and Indigenous knowledge, with Iñupiat Elders as a central focus in the learning process. Bringing Elders to the classroom or on field trips on a regular basis provides traditional ecological knowledge related to the subject will lead to a culturally responsible science curriculum. Alaska Native students will be empowered by learning through ways that ties into their culture, land, and values.

References

- Kawagley, A.O. & Barnhardt, R. (1998). Education Indigenous to Place: Western Science Meets Native Reality. Alaska Native Knowledge Network. Retrieved from <http://ankn.uaf.edu/curriculum/Articles/BarnhardtKawagley/EIP.html>
- Nicholas-Figueroa, L. Hare, R. van Muelken, M. Duffy, L. & Middlecamp, C. (2016). Ilisagvik Tribal College summer climate program: teaching STEM concepts to North Slope Alaska high-school and middle-school student. *Journal of Environmental Studies and Science*. p. 1-10. Retrieved from <http://link.springer.com/article/10.1007/s13412-016-0413-6>.