Cultural Relevance in Chemistry Education: Snow Chemistry and the Iñupiaq Community

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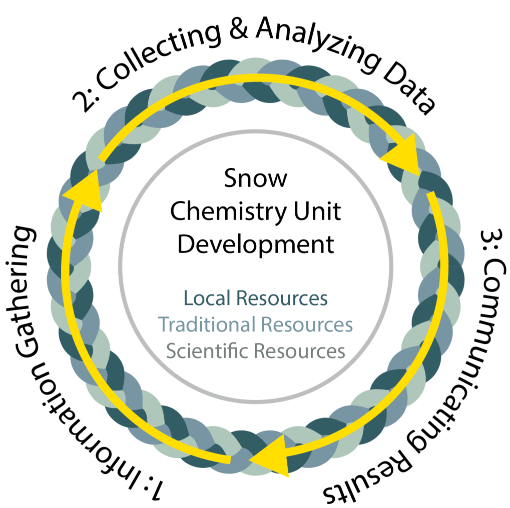
ABSTRACT

Science education generally portrays content from an acultural perspective, and as a result, non-majority students often struggle to relate material learned in class to their lived experiences and culture. Cultural relevance is gaining momentum in broader education reform movements to relate content in the classroom to students' cultures and worldviews. Even with this momentum, examples implementing culturally relevant instruction remain sparse in science education, and in chemistry education in particular. This article outlines a collaboration between Iḷisaġvik College, a tribal college in Utqiaġvik, Alaska, and the University of Michigan, in Ann Arbor, Michigan, to learn more about how culture and context influence the design and implementation of culturally relevant curricular materials for introductory chemistry. Throughout the process, we work with community members, Elders, research scientists, Iḷisaġvik College professors, and students to develop an environmental chemistry research project focused on integrating local, cultural, and scientific resources to explore Arctic snow processes. Participating students engaged in a three-part unit, including information gathering from cultural and scientific resources to develop research questions, collecting and analyzing samples from the local area using analytical methods, and interpreting the data and communicating results to the greater community. Here we outline the design considerations used to construct and implement a culturally relevant chemistry unit. We explain how we cultivated relationships with the community and identified resources that students used to inform classroom activities. We also describe how culturally relevant education relates to the unit and identify areas where we are still growing as we engage in the design process. Finally, this project demonstrates how a student-driven environmental chemistry project can connect introductory science students to their community while engaging in authentic research practices.

GRAPHICAL ABSTRACT



KEYWORDS
First-Year Undergraduate/General, Second-Year Undergraduate, Analytical Chemistry, Environmental Chemistry, Curriculum, Learning Theories, Minorities in Chemistry, Nonmajor Courses, Undergraduate Research

INTRODUCTION

The lack of retention of non-majority students from science, technology, engineering, and mathematics (STEM) has sparked concern from national organizations.[1-3] In response, chemistry educators have looked at ways to make STEM content relevant to students' everyday lives.[4-7] Often, chemistry classrooms focus on scientific methods and content rather than a connection to community and personal relevance.[8] Although cultural and socially-negotiated processes govern the construction, validation, and communication of scientific knowledge,[9-11] the results of this process are presented as settled facts in the classroom, which is discouraging to individuals from non-majority groups who may have their own perspectives.[12-14] Activities containing science material that is relevant to students' social identities support their sense of belonging and esteem, helping them succeed in the classroom environment.[15] Further, education research reveals that curricular resources are a product of cultural value sets[10, 16] that affect students' self-perception and success.[17-19] Generally, there is an absence of instruction in chemistry education that considers, recognizes, and affirms non-majority cultural perspectives. Here we describe an environmental chemistry research unit that engages students' traditional and local knowledge alongside western science knowledge to investigate snow chemistry in the Arctic.

Culturally Relevant Education

Culturally Relevant Education (CRE) is a lens to develop curricular materials that strengthen students' cultural identities while teaching content and scientific practices embedded within a chemistry classroom.[20-22] CRE integrates students' cultural and community resources[23] with science curricula to promote engagement of non-majority students in secondary settings[22]. CRE includes four tenets:[22, p. 167]

(1) Developing *connections between cultural references and academic skills and concepts*. A culturally relevant educator understands the worldviews and cultural assets students bring into the classroom and utilizes these assets to inform development of curricula.

(2) Engaging students in *critical reflection* about their lives and the world around them. A culturally relevant educator constructs activities encouraging students to consider how course material relates to their community and society.

(3) *Facilitating students' cultural competence*. A culturally relevant educator builds a classroom where students learn about their own and others' cultures while teaching students how to navigate the structure and culture of the field they represent.

(4) Working to identify and dismantle oppressive systems through the *critique of discourses of power*. A culturally relevant educator discusses the systemic inequities that affect non-majority students, promoting social justice for all members of society.

Non-majority students can struggle to learn scientific content because they often perceive a divide between the content learned in classrooms and the values, practices, and beliefs in their everyday lives.[9, 24, 25] In general, STEM education portrays the values and systems of a dominant western science culture, undermining how non-majority students experience the world.[10, 26] For example, children from the Menominee community, an Indigenous nation based in Wisconsin, are more sensitive to ecological relations in food chain networks than European Americans. Their perspective places more attention to relationships amongst species and roles that humans play within the ecosystem. As a result, Menominee students, and those with similar cultural perspectives, relate less to the presentation of food chain networks from biological texts, which limit the species represented and omit humans as contributing members of a food web.[10] Culturally relevant curricular materials would leverage Menominee cultural resources (e.g., Elders, community members, experiences in an ecosystem) to connect content to students' lived experiences while teaching scientific content.

While examples of cultural relevance are growing in other sciences[9, 10, 19, 22, 27], chemistry education has few examples of the subject. Reports show that modern films [28] and food[29] connect students' *cultural references* and lived experiences to chemistry content in the classroom. Environmental chemistry research experiences also connect chemistry content to place and culture, providing opportunities to engage with science that relate to activities and resources of direct concern to students' own communities.[13, 14] For example, Scholes focused on traditional Indigenous practices, such as toxin removal from plant seeds, and connecting them to their associated chemistry content as a way to improve student interest in chemistry.[30]While these activities connect classroom content to students' *cultural references*, further work is needed to engage in all recommended practices of CRE including *critical reflection*, *facilitating cultural competence*, and *critique of discourses of power* to allow students in promoting, utilizing, and reflecting on their cultural knowledge systems.

Cultural Relevance in the Arctic

The Arctic is warming faster than elsewhere on Earth and changing profoundly with declining sea ice extent and melting permafrost.[31] The community of Utqiaġvik, Alaska, situated at the northernmost point of the United States and home to the Iñupiat people, experiences these changes firsthand (Figure 1) The Iñupiat have lived in the Northern Arctic for ca. 10,000 years and possess an intimate knowledge of the tundra and sea ice through subsistence hunting.[33, 34] In general, Indigenous people, such as the Iñupiat, have their own ways of looking at and making sense of their communities, the world, and the universe.[25, 34-36] Education in the community is achieved by observing the natural world, adapting modes of survival, obtaining sustenance from the local environment, and using natural materials to make tools.[34, 37] Traditional knowledge is transferred through demonstration, observation, and storytelling.[34, 37, 38] Seasonal subsistence hunts, sea ice navigation, and food storage are examples of traditional knowledge that is shifting because of the changing climate, affecting the daily lives and culture of those living in the Alaskan Arctic.[33, 34]

Figure 1. Location of Utqiaġvik Alaska, home of the Iñupiat people and northernmost point of the United States[32]

Science curriculum taught in modern schools generally adheres to a western perspective, emphasizing compartmentalized knowledge that is decontextualized. This approach to science education conflicts with Indigenous populations' learning processes using direct experience in the natural world, leading to a divide between traditional knowledge structures and western science practices taught in classrooms.[39] For instance, students whose central concerns about the environment involve questions about safely navigating the sea ice and other aspects of the subsistence cycle may not see value in the standard scientific curriculum. In Utqiaġvik, there is an educational effort[40] to emphasize a holistic knowledge of the changing Arctic - a common ground between knowledge systems that students use while participating in scientific activities.[27, 39]

A vibrant history of the scientific community partnering with an Indigenous population that possesses extensive knowledge of the local environment[34] makes Utqiaġvik a place where local students can easily access authentic scientific practices while considering their own culture. For instance, co-author Nicholas-Figueroa introduced a project with a two-week program on the understanding of the carbon cycle and its impact on climate change. In this program, secondary students engaged with Elders and scientists, where Elders spoke of topics that had direct effects on the local environment and the subsistence community and scientists communicated about the fundamental relationships of the carbon cycle as it relates to the local environment.[41] Examples like this demonstrate that environmental chemistry can serve as a tool to bridge the scientific and local communities, allowing students to explore scientific concepts that are important to the community through a lens that draws upon their unique cultural resources to inform their projects.

Engaging students in research practices centered on environmental chemistry that is informed by local and visiting educators, scientists, community scholars, and Elders may contribute to a curriculum intersecting the norms and practices of western science and the traditional knowledge systems of Native Alaskans.[39, 42] Herein, we describe the design and early implementation of a culturally relevant chemistry unit in the introductory science classroom at Iḷisaġvik College, a two-year tribal college in Utqiaġvik, AK. This unit focuses on snow chemistry and processes relevant to Arctic climate change and the lives and culture of the people of Utqiaġvik. The project involves Utqiaġvik community members, Iñupiat and local students, professors at Iḷisaġvik College, active research scientists, and chemistry education researchers to learn about how culture, context, and place inform the development of a culturally relevant chemistry unit. While the project is ongoing, the lessons learned are relevant to chemistry educators and researchers now. This article outlines the considerations made while developing a culturally relevant chemistry unit, including cultivating relationships between cultures and identifying resources students use to inform classroom activities. We also describe this unit's alignment with CRE and identify areas we are still growing while designing curricular materials that place students' cultures at the forefront. Finally, this project demonstrates how environmental chemistry connects students to their community while engaging in research practices.

SNOW CHEMISTRY MODULE DESIGN PROCESS

Partnering with the Community

We co-design products to serve the greater good of the community using methods that affirm Indigenous populations.[43-46] We seek to honor participation by the Utqiaġvik community in mutually beneficial ways, such as communicating and celebrating students' findings with the community, securing feedback, and support in promoting designs to the greater Iñupiaq and education community. We recognize the importance of honoring relationships built through the project and are grateful for the knowledge that our participants choose to share.[47] This perspective requires reflection on our positionality[48] to determine how our views influence our process. Positionality recognizes power and privilege differences between the project team and stakeholders along with the historical and contemporary realities in the community.[49, 50] The project team consistently engages in reflection on specific instances in the classroom and interactions with community members to grow our understanding of power and culture and how they affect students and their families.

This partnership was built through a conversation between two of the authors, a scientist who specializes in Arctic research and the community liaison, who self-identifies as Iñupiat, with the Ukpeaġvik Iñupiat Corporation (UIC) Science, which is an Indigenous-owned and operated Arctic logistics provider for researchers in Utqiaġvik. Relationships between project members were built from the initial interaction and include a coauthor, who is a science professor, self-identifying as Black, at Iḷisaġvik College with a research background integrating local and Indigenous knowledge in the introductory science classroom. The project team contains members situated at Iḷisaġvik College and the University of Michigan (UM). The Iḷisaġvik College team brings knowledge of local and community resources, an understanding of the student populations, experience developing culturally relevant curricular materials, and connections to community members who can visit the classroom. Members of the UM team bring connections to the scientific community and experience integrating environmental chemistry research in the introductory chemistry classroom.[51] The UM component of the project team consists of White individuals who possess multiple advanced degrees in science and education. In most ways, the UM team is still learning about the effects of colonization on non-majority peoples' identities. Due to culture differences between institutions, we rely on relationships and interactions with the local community to guide our design and implementation of the snow chemistry unit. We also consult with individuals familiar with Iñupiaq culture (e.g., Elders, subsistence hunters) and invite community members into the classroom to inform our project.

Unit Design and Adaptation

To begin the curriculum design process with Iḷisaġvik College, the UM team visited Utqiaġvik in spring 2019 and spent time learning about the community. The professor at Iḷisaġvik College invited UM team members into her classroom and discussed her approach to and beliefs on teaching, how she supports her students, and her perspectives on incorporating tenets of Iñupiat culture in her classroom. The team talked with students about their experiences learning science in Utqiaġvik and visited multiple classrooms at the secondary and postsecondary levels to learn about how science is taught in schools. During the visit, UIC-Science hosted a public presentation in which we outlined our design plan for the student-driven research project to community members, offering a space to solicit feedback on increasing community involvement in the project.

Our experiences from the first trip framed a collaborative workshop at UM in summer 2019, where the project team discussed ways for students to reflect on their cultural identity while engaging in science practices surrounding snow chemistry. We constructed activities where students identify cultural resources that inform a research project, reflect upon those resources in relationship to content learned in class, and develop a research question aligning with the project's cultural and scientific elements. We discussed ways to leverage community participation throughout the course to connect students directly to community members to inform their projects.[52] The project team highlighted the use of ion chromatography at UM to measure inorganic ions in snow samples in addition to the classroom-based practice of using accessible titration methods to measure chloride concentration.[51] We frequently consulted the notes and recordings of both team visits while initially developing the unit's components and over the next several semesters of implementation. While designing the materials, the project team collaborated consistently to ensure that the snow chemistry unit was responsive to Iñupiat culture and feasible for the classroom context at Iḷisaġvik College.

Design-Based Implementation Research (DBIR)[53] is well-suited to the culturally-sensitive nature of our project due to its focus on collaborative and iterative engagement to sustain the unit past our involvement in the community. Principally adapting curricular materials for a specific context in collaboration with stakeholders (e.g., Iḷisaġvik College instructors, community members, and students) is an important component of DBIR. We implemented three iterations of the snow chemistry unit at Iḷisaġvik College in Fall 2019 for a first-semester general chemistry course, Winter 2020 for an introductory climate change course, and Fall 2021 for an introductory-level chemistry and society course. Enrollment in the courses included 18 total students, many self-identifying with a range of cultures including Alaska Native (Iñupiat), Filipino, LatinX, and White. The project team collaborated in weekly meetings, discussing general impressions of the course, adaptations to the unit, and logistical constraints. At the end of each semester, the project team reflected on the support structure and classroom interactions throughout the semester to inform the unit's adaptation for subsequent iterations.

2a

Section 1: Information Gathering and Developing a Research Question	Listening to Stories from an Iñupiaq Elder
	Information Gathering & Planning Community Interviews
	Snow Chemistry POGIL
	Summarizing Knowledge & Developing a Research Question
Section 2: Collecting and Analyzing Snow Samples	Snow Sampling Experimental Design & Mock Trial
	Chat with Science Professor
	Snow Collection
	Physical and Chemical Snow Measurements
Section 3: Interpreting Data and Communicating Results to the Greater Community	Measurement Data Analysis and Interpretation
	Telling Story of Research/Public Presentation
	Class Reflection

2b

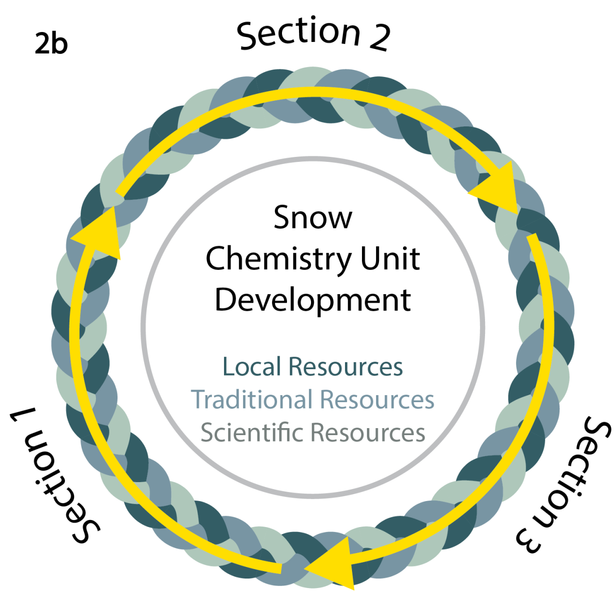


Figure 2a. Overview of the components of the three sections of the snow chemistry unit. Figure 2b. Overview of the application of CRE principles in the context of culturally-motivated environmental research, where students engaged in information gathering to develop research questions, analyzed local snow samples using analytical techniques, and interpreted the data and communicated their results to the greater community for celebration and feedback. Students in future iterations use prior feedback and results along with new information to inform deeper research questions. A braid represents the local, traditional, and scientific resources used by students to inform their project since the cultural resources are intertwined.

Snow Chemistry Unit

The snow chemistry unit consists of three sections (Figure 2a). The first section focuses on gathering information about snow and ice from the local community and from western science to develop a research question. This section includes listening to stories about the changing snow and ice from an Iñupiaq Elder to guide students on prior knowledge produced by community members and scientists before choosing a question to study. The students develop an interview protocol, with guidance from an Anthropology professor at Iḷisaġvik College, and talk with people in the community to refine what they could study in the project. While students conduct interviews, they also learn in the classroom about prior snow chemistry research through a Process-Oriented Guided-Inquiry Learning (POGIL) activity.[54] We recognize that environmental chemistry and POGIL communities use the term 'model' differently, so we are defining it as a representation of a scientific phenomenon[55] that grounds students' discussions while participating in the POGIL activity.[54] Within the POGIL activity, students collaboratively work through questions associated with models based on figures from primary snow chemistry literature to learn about pathways of sea salt addition to the Arctic snowpack.[56] Throughout this section, students reflect on each activity, how the activities are related, and elements of culture that could inform a research question. The section concludes with students developing research questions to guide the collection and analysis of local snow samples.

The second unit section focuses on student analysis of snow samples collected near Utqiaġvik. After developing a research question, the whole class develops a snow sampling experimental design protocol outlining outdoor safety, materials needed, procedures to avoid contamination, and sample storage methods. When possible, the students test their protocols in small groups by conducting a mock snow sampling trial outside of the laboratory and revise their protocols from their experience. Before collecting samples in the field, students present information used to inform their research question and their snow sampling protocol to a science professor who conducts snow chemistry research in Utqiaġvik. After receiving feedback, students reflect on the process of interacting with a science professor and their sample collection protocol adaptations. Snow sampling is dependent on local weather conditions and safety considerations, and any snow sampling occurring outside of town requires guidance of local community guides (e.g., polar bear guards) to ensure safety. Students use the Mohr method[57] to measure snowmelt chloride concentrations through titration using silver nitrate and a potassium chromate indicator, following previous application in the introductory chemistry classroom for this purpose.[51] When snow sampling was not feasible due to COVID-19, a large dataset of Utqiaġvik snow inorganic ion concentrations, previously obtained by UM general chemistry students using ion chromatography,[51] and maps of sampling sites were made available to the Iḷisaġvik College students to choose sample data to answer their research questions, which were adapted as needed based on the data available.

Students interpret and share their results with the community in the third section. Students graph their chloride concentration data in a manner that aligns with their research question, using examples from literature[56, 58, 59] and receiving feedback from the project team to further their computation skills using spreadsheets. Once students construct representations of data (e.g. graphs) and discuss their interpretations, teams of students construct presentations telling the story of their research project. Due to logistical constraints, student presentations occurred virtually through public presentations. In the future, we are planning in-person presentations in an accessible space for the community, so they can respond and offer feedback to be incorporated in future iterations of the project. The unit concludes with an activity where students reflect on their experiences with the project, what they learned, and changes they would make to guide future students in their projects.

FINDINGS

This collaboration engaged a range of stakeholders from the community of Utqiaġvik to learn about how culture, context, and place inform the development of a chemistry unit that affirms diverse cultures. In doing this, we explore how aspects of this unit align with the four tenets of CRE outlined in Aronson & Laughter (2016): *Connections between Cultural References and Academic Skills and Concepts, Cultural Representation and Critical Reflection, Facilitating Students' Cultural Competence,* and *Critique of Discourse of Power.* Each section below discusses a tenet of the framework by discussing the definition and operationalization of the tenet in the unit's design and implementation. We then provide an example from the body of evidence that we collected through the partnership. Assigning researcher-generated pseudonyms can be harmful to non-majority populations' cultural identities;[60] therefore, we use general terms (e.g. student 1) with a brief description of the student's cultural background and experiences that are important to the example. We also use gender neutral pronouns (they/their) to protect the identity of students due to the small number of participants in the course. Each student consented to participate following our IRB protocol.

Connections between Cultural References and Academic Skills and Concepts

Students possess a wide range of cultures, experiences, and resources that contribute to their identities and influence their experiences in academic spaces[23]. CRE leverages the knowledges that students bring to inform instruction. As a design principle, we constructed activities where students identify and explore resources present in their community and use those resources to inform scientific practices. For instance, students learn about snow from an *Elder visit to the classroom*, conduct community member interviews and explore artifacts at the Iñupiat Heritage Center through an *information-gathering assignment*, and learn about inorganic ions in the snowpack through the *snow chemistry POGIL*. Students use these resources to construct research questions and design sample collection strategies that explore chloride content of the local snowpack. Students employ a diversity of resources, many of them from traditional, scientific, and local knowledges (Figure 3). For the purposes of distinguishing cultural references from other resources, we label the resources as traditional,

Figure 3. Summary of resources used by students to inform their research question. The project team applied the categories in Figure 3 for the purposes of this publication.

scientific, and local knowledges (Figure 3). We defined traditional resources as knowledge that originated from Iñupiat knowledge systems (e.g. Elder visit to the classroom, Iñupiat Heritage Center, community member interview). Scientific resources are knowledge that students use from a western science perspective (e.g. snow chemistry POGIL). Local resources are knowledge that comes from the community that is neither Iñupiat nor from the scientific community (e.g. local residents). We found resources around Utqiaġvik that informed students' projects, identified in Figure 3, from student artifacts and classroom discussions. We recognize that splitting up knowledge sources is a Western Science-centered depiction of knowledge that may not translate how Indigenous communities think about knowledge[34, 39]. However, to design for CRE, we need to consider how these knowledges are woven together as students often viewed these resources as blended. For instance, some Iñupiaq students consider Iñupiat knowledge of whaling patterns as scientific knowledge passed down in experiential learning settings (e.g. while whaling). Often, students did not distinguish between scientific and traditional knowledge systems and could recognize the intertwined nature of knowledge sources, represented as a braid in Figure 2b.

One example of this tenet of CRE comes from student 1, who identifies as Iñupiaq and who is considered to be non-traditional in most university contexts. During the Elder visit in the classroom, students asked questions about potable water sources while hunting or whaling. The Elder reflected that drinking melted surface snow makes someone thirstier and that digging to lower layers produces water that someone could drink. Student 1 reflected that the Elder's comments reminded them of seasonal caribou migration patterns around Utqiaġvik and their experiences hunting—caribou instinctively migrate towards sea ice due to the mineral content in the snow. They explored this knowledge, utilizing yearly caribou migration patterns from the Bureau of Land Management and considering the origins of sea salt in the snowpack from the snow chemistry POGIL to consider the intersection of these data to investigate areas where caribou migrate around Utqiaġvik. Their research question focused on differences in chloride concentration based on proximity to caribou herds and snow depth.

Cultural Representation and Critical Reflection

Culturally relevant educators engage students in *critical reflection* by developing curricula and activities that support students' understanding of the cultures represented in a classroom. Educators engage in *critical reflection* by constructing activities that dialogue about culture, leading students to develop an understanding of and value towards multiple cultures. Within our snow chemistry unit, students engage in *critical reflection* through the *information gathering assignment* by reflecting on information learned from community resources, community member interviews, and summarizing their knowledge sources in classroom discussion. After presenting their research questions and snow sampling protocols for the *chat with the science professor* activity, students compare the science professor's cultural background and scientific knowledge to their identities and scientific knowledge. At the end of the snow chemistry unit, students reflect on their classroom experiences through their *community presentations* and a final *class reflection*. Initially, we developed many of the reflective prompts as formal, written exercises. To align the classroom and reflective prompts with the Iñupiat's history of verbal storytelling, we shifted our initial reflective prompts to informal, oral reflective class sessions.

During the *community presentation*, students presented their research design and findings to community members and project team. One high school student, who enrolled in the class as a part of a dual enrollment program, engaged in *critical reflection* with another student, who was in their first semester at Iḷisaġvik College, at the end of their presentation. Student 2 identifies as Iñupiaq, and student 3 identifies as Filipino. Student 2 reflected that the unit challenged them to "think outside of the box," requiring them to use a variety of community and scientific resources in their project. Specifically, they discussed the importance of incorporating community members' voices while considering their research questions and sampling protocol. Student 2 also discussed Elders' direct knowledge about the changing Arctic since they experienced climate change throughout their lives. Student 2 recognized that they would become an Elder and would need to inform others about their experiences with climate change in Utqiaġvik to help their community. Student 3 expanded upon student 2's reflection, describing how they used resources outside of the internet to complete the project. Student 3 described how their high school science projects make them use only online resources to find specific answers. In contrast, this project encouraged Student 3 to seek community and scientific resources to investigate open-ended issues. By developing research questions and snow sampling protocols based on the knowledge of several sources, student 3 recognized the influence of multiple worldviews while designing their research project.

Facilitating Students' Cultural Competence

CRE fosters students' *cultural competence* by creating space where students learn about their own and others' cultures, emphasizing the importance of cultural diversity and validating students' cultural identities. Educators construct reflexive spaces where students learn about others' lived experiences and perspectives, using this information to reflect on their own identities.[61] Activities building *cultural competence* allow students to take pride in their culture while learning about other cultures in the process. Students engage with *cultural competence* in the snow chemistry unit in several instances. Community members discuss their experiences with snow and ice during the *information gathering assignment,* and students compare and contrast these experiences with their own. Several interviews focused on shifting cultural practices due to changing sea ice extent, providing students with knowledge about Iñupiat culture and environmental changes occurring in their community (e.g. melting permafrost). Students also summarize their knowledge sources in the *information gathering assignment,* discussing their findings from literature sources and interviews with community members. After the *chat with the science professor* activity, students compare and contrast the professor's cultural background and scientific knowledge to their own. These activities teach students to navigate multiple world views as they construct their research questions and snow sampling protocols.

A partnership between student 4, who identifies as a White and non-traditional student, and student 5, who identifies as an Iñupiaq student, demonstrated the *facilitation of cultural competence.* Prior to the course, student 4 had limited knowledge about Iñupiat cultural practices and could not describe their own culture. Student 5 viewed classroom science as an embodiment of White culture, assuming initially that student 4's views aligned with this perspective. Both students explored their perceptions of the other students' culture from the context of snow chemistry during the *chat with the science professor* activity when they described the knowledges that informed their research question.

For instance, student 5 told stories about their parents' and grandparents' experiences living in Northern Alaska, and student 4 reflected on these examples throughout their research project. Student 4 also discussed that student 5's experiences in Northern Alaska provided a perspective where student 5 and the science professor contained different types of expertise on the subject. For example, while the science professor could describe complex phenomenon about a particular part of the nature of snow and ice, student 5 could discuss the different types of snow and their relationship to lived experiences affecting their life (e.g., finding water sources). Student 4 described that they did not align with the scientist, stating that "scientists see the world as black and white, and [they approach] the world more artistically." Student 5 never considered this perspective before and asked questions about how student 4's and the scientist's views differed. Both students noticed that their cultural perspectives could construct a more nuanced research question that involved a complex phenomenon and its cultural implications. By the end, both students could point out interactions where they learned about differences in perspectives of science and the environment that were a part of Iñupiat and White culture.

Critique of Discourse of Power

It is important to recognize the effects of power and privilege when discussing issues that involve the intersection of cultural, educational, and community values.[50] Nieto and McDonough[62, p. 371] mention: "focusing on diversity and multiculturalism without attending to issues of power, racism, and whiteness only serves to reproduce systemic inequities under the guise of multicultural education." CRE focuses on building an environment where students learn about and critique power structures so that they can navigate, identify, and dismantle inequitable structures affecting their daily lives, communities, and professional outcomes. Designing structures promoting this type of discourse while aligning with the objectives of the snow chemistry unit proved challenging. Students could reflect on experiences and perspectives regarding *discourses of power* following the *chat with the science professor* activity. To solicit feedback from the professor, students present their research question, sampling plan, and knowledge sources that informed their experimental design. In the reflection activity, students had a choice of prompts to which they could respond. For one prompt, they could discuss their feelings about the feedback process, changes to their research question and sampling protocol, and places where they are resistant to change because of cultural factors. This activity aimed to capture tension between cultural knowledge systems and the western scientific perspective, offering a space where students could discuss the power dynamic of *expertise* and how it affected their actions.

Most students chose to answer other reflective questions that did not relate to *critiquing discourses of power*. The few students that answered this question responded only in a positive manner. For instance, students reflected that they revised their initial research question based on feedback because "[the professor] knows much more about snow" and thought suggestions would provide a better experimental outcome. Other students commented that they based their research question revisions on interactions with UM graduate students or the *snow chemistry POGIL* activity. While we recognize the professor, graduate students, and the *snow chemistry POGIL* activity are valid scientific resources that students use to inform experimental design, students were hesitant to challenge this scientific perspective. From a cultural lens, it is important to note that shared Iñupiaq values[63] students learn within families and the education system could affect how they engage with the prompt. For instance, *Respect for Elders* and *Avoidance of Conflict* are deeply engrained values for students, so they could be reluctant to insert their ideas if they viewed the science professor as their Elder and wanted to avoid conflict in this situation. Based on this, we are exploring ways to better engage students in *critiquing the discourse of power* through the unit.

CONCLUSIONS

Designing for Cultural Relevance

CRE recognizes and utilizes students' cultural resources to engage in course materials. In our case, this involves engaging with local, traditional, and scientific resources that students use to develop research questions around snow chemistry. The project team utilizes a three-part cycle (Figure 2b) to engage in context-based authentic environmental chemistry research in the classroom: (1) students explore cultural resources about snow and ice through information gathering activities, using this information to develop research questions that are relevant to their culture and daily lives; (2) students collect and analyze data using analytical techniques accessible in the Ịlisaġvik College science classroom; (3) students interpret and communicate their results back to the community so that they could celebrate their work and solicit feedback from people who are knowledgeable and interested in the subject. This cycle is iterative, meaning that previous research questions, results, and community feedback inform how future students design their research question and experiment. We represent local, traditional, and scientific worldviews as a braid wrapping around the cycle, informing each step and connecting students to parts of their identity they explore and celebrate. Each aspect of the unit is student-driven, where the instructor facilitates students' interactions with the community and teaches the titration method used to analyze the snow samples. While this unit relates to our particular snow chemistry project in the Alaskan Arctic, the general components have the potential to transfer to other classrooms serving students who identify with non-majority cultures to connect cultural resources and environmental chemistry research in the introductory science classroom.

Flexibility as a Design Principle

Throughout the implementation process, the project team considered contextual characteristics of the community and location that affected the outcome of the unit between iterations. During the project, we regularly discuss cultural differences between institutions. For instance, many community participants who volunteered with the students held important community positions that took precedence over course events. Because community participation with the students is critical for the project, we often shifted to accommodate for community members' responsibilities. To do this, we reframed selected activities based on who was available and what was most advantageous for the context, making the activities modular in nature. As a result, if an Elder became unavailable, we had other cultural activities to move the students forward in their project. The community's culture is characteristically flexible, and the Iḷisaġvik College professor regularly accommodates the needs of students due to cultural events and weather conditions. Examples of these accommodations include professors shifting syllabi to ensure full content coverage and using digital communication platforms (e.g. Zoom) to accommodate remote learning. As a team, we reflected on the norms of our collaboration[64] and considered potential shifts as we adapted the materials to increase flexibility. Re-conceptualizing the activities to be modular in nature also helped to design the unit with flexibility in mind. While these specific cultural characteristics may be unique to Utqiaġvik, the focus on flexibility could be transferred to other contexts and is a critical aspect of the DBIR framework.

Focus on Connecting with the Community

It is important to promote and honor the community engaged throughout the project. We found it is critical to engage with community members early in the design process, listen to their concerns and suggestions, and respond with concrete design adaptations. Often, curriculum design and research occur separately from the community, leading to curricula that does not align with community values[65] and research that captures a limited cultural perspective.[47] It was helpful to incorporate many perspectives from esteemed community members for two reasons. First, it expanded our views of expertise beyond the project team to include a range of individuals engaging in a broad scope of activities related to snow, keeping us from inadvertently promoting the settler-colonial narrative rampant in outreach and research activities with Indigenous populations.[44, 47] Second, it distributed responsibility in relating to students to include people involved in the students' lives outside of academic environments. This approach relates more closely to how many people learn in Utqiaġvik through experience and intergenerational guidance.[37, 38] These community interactions served as concrete and experiential ways students could reflect on cultural differences and the implications of their work.

Finally, building trust and rapport with a community takes time and commitment by the project team--the project's foundation was built after years of interaction between several of the project team members and with the Utqiaġvik community. To engage in the discussion of cultural resources, it is necessary for the project team, especially those from UM, to adopt a position of extreme humility as we are outsiders in the community and feel honored to collaborate within cultural knowledge systems that deviate significantly from our own. This stance allows us to cultivate sustained relationships with the community informing *how* we can design culturally relevant activities for students in our classrooms.

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ACKNOWLEDGMENTS

We thank the National Science Foundation for funding the project (Award Number: 1821884) and for supporting a co-author through the Graduate Research Fellowship program (Award Number: 1841052). We would like to acknowledge the community of Utqiaġvik for their warm hospitality and willingness to share with us their culture and community resources. We also thank Iḷisaġvik College, and the many instructors who welcomed the UM team into their classroom and homes, to show us what makes Utqiaġvik a unique place to teach, learn, and live. We recognize the work done by the Ukpeaġvik Iñupiat Corporation for supporting the project team while working with the people of Utqiaġvik. We appreciate the hard work and dedication that Iḷisaġvik College students put in while participating in the unit and the Utqiaġvik community members who volunteered to guide the students in their projects. We acknowledge J.J. Mayers and Ina Zaimi for their contributions to the initial design of the workshop and help in making the Iḷisaġvik College professor's visit to UM more hospitable. Finally, we thank Leah Bricker, Vilma Mesa, Jared Ten Brink, and Anne Gere for conversations that refined our understanding of the history of Indigenous peoples in North America, power and privilege in the classroom, and our positionality and its effects on the research process.

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