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Engaging Students in Science Courses: Lessons of Change from the Arctic

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Abstract

Where you live should have something to do with what you teach. In the Arctic, this idea of place-based education—teaching and sharing knowledge that is needed to live well—is central to the UARCTIC consortium and the 4th International Polar Year educational reform effort. A place-based issue oriented context can engage students in chemistry concepts when it intersects with their experience and lives. This article examines the rationale and means of integrating local concerns such as world view, culture, traditional knowledge and policy into both general and specialized chemistry courses. More broadly, capacious place-based issues should be widely adapted by all curriculum reform efforts to demonstrate the connectivity between science and societal understanding of technological options. A case in point is the inclusion of indigenous perspectives in a non-majors general chemistry course when the concepts of scientific method, ice and water resources, genetic engineering, etc. are discussed. In a specialized course on radioactivity in the north, topics connected nuclear chemistry and radioactivity to people and energy. The local landscape should be central to science courses and involve issues relevant to stewardship, a component of the indigenous world view. The historical issues can be connected to current nuclear energy and uranium mining as they relate to the risks and benefits for the local community. This article will make the case that curriculum reform that focuses on real-world topics will not only engage students so that they perform well in class but also spark their interest so that they continue learning after the course is over.

Keywords

Place-based Science Education; Environment; Climate Change; Arctic Science; UARCTIC; Culture and Stewardship; Civic Issue Engagement

Introduction

In undergraduate chemistry courses, especially those courses for non-science majors, the problem of connecting our courses with the learning needs of our students has been well documented (AAAS, 1990; Tobias, 1990, 1992; Seymour and Hewitt, 1997). The “I hated my previous chemistry course” is an all too common lament by the liberal arts students who take our courses (Middlecamp, 2008), especially minority students (Kawagley, 1995). This same refrain may be heard by students in geology, physics or economics courses as they are

traditionally taught at state colleges and universities. The lack of engagement with science principles needed to understand and live in a modern technological society impacts the learning for many students, especially women and minorities (AAAS, 1990; NAS, 2000). Chemistry and other sciences should be embedded in a holistic exploration of broader, real-world social and political issues that students, as citizens, are interested in (Guarasci, 1997; Pinrich and Schunk, 2002). Without this, we are less likely to connect to our students and engage them in learning (Kawagley, 1995; Sobel, 2004).

Over the last 20 to 30 years, there have been major advances in cognitive science (Bloom, 1956; Pintrich and Schunk, 2002; Root-Bernstein and Root-Bernstein, 1999) and educational theory related to how people learn (Bonney, et al 2009; NAS, 2000). These advances provide the theoretical base for several large curriculum reform projects. One such project, funded by the National Science Foundation, is SENCER, Science Education for New Civic Engagement and Responsibilities (Middlecamp et al, 2006). This national dissemination project strives to develop faculty who can engage students by using capacious real world issues in their science, technology, engineering and mathematics courses. SENCER courses try to connect science and public interests by teaching through these complex issues in the local context of the student to the underlying scientific principles. SENCER courses aim to build scientific literacy for participation in the social economic system. The more students can see relevance to their own everyday lives and to community, the better their understanding of the principles and their learning outcomes.

Courses that follow the SENCER approach of connecting science with civic issues are especially important in the culturally diverse Arctic. If anything, through these connections, polar researchers and educators (Streever, 2009; Barnhardt and Kawagley, 2010) would argue that issues such as climate change, energy production, waste reduction and sustainable use of resources are more relevant than ever to students as they enter society. This emphasis can be seen in the recent International Polar Year (IPY) activities. For the first time, the human component was included in the form of education and public outreach as an explicit segment of the international research effort.

In this paper, we will describe how a holistic approach was used in the UARCTIC IPY education effort to provide access to basic science education for northern people. More specifically, we will describe a project at the University of Alaska Fairbanks and challenges we faced as instructors and as an institution. We will give several examples of “SENCERizing” both general and specific topics in chemistry courses. We also will demonstrate how to include traditional ecological knowledge when it intersects with a science principle or local real world issue, in the process, adding relevance to the learning process. Exposure to traditional knowledge broadens the students’ world view and engages them with their communities. It recognizes and validates what students currently know and builds upon that knowledge (Stephens, 2003). Besides the values of sharing Arctic knowledge and access to education for all Arctic people, the UARCTIC focuses on including the many different indigenous people and their cultures in the north in its education effort. The article concludes by discovering the challenges and the constraints in curriculum reform and the implications of the IPY experience for the continued dissemination of this approach.

IPY, the UARCTIC and SENCER for Northern Society

The International Polar Year was a two-year global campaign to expand our understanding of Earth's polar regions and their people. Thousands of scientists worldwide collaborated on hundreds of Arctic and Antarctic projects, and shared the results. IPY strengthened our understanding of our changing planet, and leaves a legacy of knowledge for generations to come, including exposing scientists and the public to indigenous ways of knowing (Cochran et al, 2008).

The fourth International Polar Year (2007-2009) focused on Earth's atmosphere, ice, land, oceans, people and space. More than 300 institutions from 38 countries participated. Of the 208 clusters of projects endorsed by the IPY International Programme Office, 28 percent have participation from the University of Alaska Fairbanks, America's Arctic University. During the International Polar year, the UARCTIC coordinated education efforts by bringing a network of scholars, scientists and educators together to inspect challenges and opportunities in the Arctic. For example, the IPY Young Researchers' Network, a group of graduate students, postdoctoral fellows and early-career researchers, was established in 2006 to promote Arctic research through informal lectures, community-based monitoring projects, and activities to engage K-12 educators and their students (www.uaf.edu/ipy).

Another first in the 2007-09 IPY was the inclusion of the social and life sciences in its overall strategy—the others concentrated only on geophysical themes. This expansion of IPY reflects the fact that polar phenomena are complex and extend across national and disciplinary boundaries. The desire for a coordinated approach led to better research outcomes and cost effectiveness (Petersen, 2009). Also evident in the IPY was the conviction that outreach is a very important part of the process; much greater attention has been paid to explaining how climate change in the Arctic affects the entire globe and to raising the general level of knowledge about the Arctic. This inclusion of social relevance and engagement coincided with the developing curriculum reform efforts at the National Science Foundation in the United States of America. In this evolving technological world, science has to involve all students directly in the multi-faceted and iterative process of scientific investigation. It fails when it becomes the private reserve of individual disciplines focused on creating science majors.

The UARCTIC as a network was launched in 2001 as a supplement to universities working in the north with the endorsement of the Arctic Council's senior officials. Beginning with 33 member institutions, the network has grown to include 121 institutions of which 83 are higher education colleges and universities. The diversity of UARCTIC's member institutions is reflected by their student numbers, varying from small northern indigenous colleges to large research universities. Most UARCTIC higher education institutions have less than 3,000 total students (47%), 31% have between 3,000 and 10,000 students, while the remaining 22% have 10,000 or more students. Some measure of the membership's geographic range in the North can also be seen from the fact that 41 of UARCTIC's members are located on or above the Arctic boundary as defined by the Arctic Human Development Report. Collectively UARCTIC's members have over 700,000 students and 50,000 faculty on their staffs (Olsen, 2009).

The Baccalaureate of Circumpolar Studies (BCS) was the first key educational endeavor for the UARCTIC at the undergraduate level. Its goal is to be an undergraduate program that provides a solid understanding of Northern issues, integrating social and natural sciences with local indigenous knowledge. The BCS-programme consists of an introductory course, six core courses, and several advanced level options, all described on UARCTIC's homepage www.UARCTIC.org. The first course introduces students to the landscape, peoples and issues of the circumpolar region, i.e. the place. Beginning with an examination of the geography, biological and physical systems of the Subarctic and Arctic, the course describes the diverse peoples of the region and explores indigenous world views. The history of the circumpolar world is treated in a broad fashion, to provide grounding in the events and developments that have created the region's contemporary characteristics. The second part of the course surveys some of the particular issues facing the region, including climate change, economic, political and social development. This course ultimately is intended to stimulate interest in the circumpolar world. Following this introductory class is a series of three (two-semester) courses: "Land and Environment"; "Peoples and Cultures" and "Contemporary Issues of the Circumpolar World". The student can then choose to continue to study one of 13 Advance Level Options that focus on topics of particular relevance to the people of the North. The diverse options include, for example:

- Aboriginal Public Administration;
- Circumpolar Ecosystems, Resource Use and Management;
- Northern Land Contaminants.

The University of Alaska Fairbanks helped develop the Land and Environment courses using a Science Education for New Civic Engagement and Responsibility (SENCER) philosophy. SENCER is a reform movement in science education that fits well with the UARCTIC values of access, sharing and a place-based educational focus on northern issues. Our goal was to connect science to important everyday issues. The Arctic is a sensitive indicator of the vulnerability of our planet, and is often called the "early warning system for the world". Its cold-climate ecosystem makes the Arctic particularly sensitive to disturbances and to the accumulation of toxic substances. The unique fragility of the Arctic underscores the impact of human activities. Given the vulnerability of high-latitude ecosystems, students need to learn science through real world Arctic contexts that require, if not demand, knowledge of science. Past and emerging problems in the North require solutions that in turn serve as model for future stewardship (Hild, 2010). Since the biocomplexity of the Arctic is so tightly linked to the entire global ecosystem, no discussion of our planet's future is complete without including the Arctic, its people and the cultures that were developed in a place of extremes. "What do we need to know in order to live well in this vast region?" is a critical question for the Arctic science curriculum. Credible and relevant answers will necessarily include traditional knowledge and the underlying world view (Cochran, et al, 2008; Kawagley, 1995).

Achieving sustainability in the Arctic and improving the human condition requires a practical understanding of several scientific fields, so education needs to be highly interdisciplinary in nature. For example, an argument could be made that nuclear power in rural villages could reduce dependency on oil. In fact, Alaskan rural villages are currently

considering the new small pellet nuclear technology for power plants (Fairbanks Daily Newsminer, 2008). Russia is proposing floating nuclear reactors in the Arctic Ocean (Fairbanks Daily Newsminer, 2008). What do our students of today and citizens of tomorrow need to know to make informed choices about the issue? And which of our students will choose careers dedicating themselves to pursuing the answers? Relating issues of human and industrial development to decisions in public policy and scientific research is a critical function of education. Complex questions arise across the Arctic today from the long-lasting effects of earlier development and extraction – and Arctic change has accelerated over the last hundred years (Krupnik and Jolly, 2002; Flannerey, 2005). While global warming is altering land and seascapes around the north, the Arctic is also a sink region for contaminants (Godduhn et al, 2003; Dunlap, et al, 2008). Global atmospheric and ocean patterns tend to carry pollution toward the poles, but there is no mechanism to transport them out and they accumulate in the food web. These are issues of food security for thousands of communities in the circumpolar north. . The hidden danger to wildlife and human health from long-term low-dose exposure and the cumulative effects on the human body are of great concern to Native leaders (Davidson and Napoleon, 2010). Recent broad-based discussions (Cochran, 2004) throughout the circumpolar north reveal growing concern over chronic exposure to pollution and radioactivity, and their transmission through the food web. In the past, radioisotopes have been transported up the food chain from lichens to caribou and could impact subsistence food users and wolves. What can past accidents and cultural impacts on Arctic people teach our students of today? Questions about pollution are relevant to all people in all societies (Flannery, 2005). Such issues are not usually well covered by disciplinary approaches because of their complexity, but many students are eager for applied, place-based thinking.

Clearly, the development of science-based knowledge is the foundation of long-term stewardship to insure the future for generations of Northerners. A major goal of these Arctic science courses should be to demonstrate how past legacy of activity led to stewardship and involvement of cultural values and traditions as a means of advancing public policy (Duffy et al, 2009). The intellectual groundwork has been laid by the SENCER project. Majors and non-majors alike would be served by courses that follow and complement either the BCS initial course or an introductory university course. These place-based, follow up courses should engage the student in discussing important policy issues of the North that link to science. By adapting a model course (SENCERizing) to the Arctic from the successful nationally disseminated courses of SENCER, in which students learn science by teaching through the complex, contested issues that societies face today, students will learn what they need to know to live well in their northern communities. A focus on place is to understand that a “rooted” learner exists within the real world (Sobel, 2004).

The courses discussed here used the SENCER model to articulate learning goals beyond “covering” content by emphasizing the environment as an integrating context. The complexity and relevance of the environment give us the ultimate forum for integrating across disciplines and cultures:

1. How public policies relating to health, occupational safety, defense and environmental protection require an understanding of scientific knowledge, and
2. How communities of people, especially indigenous people, faced and continue to face challenges to their land and cultural heritage in relationship to these public policies.

In reality natural ecosystems and the socio-cultural system of communities are holistically integrated as indigenous world views have long recognized.

“Culturally responsive science curriculum attempts to integrate 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 understandings formed from their experiences in the world, and that the role of school 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. 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).

To carry reform into our science curriculum and to expand the offerings of UARCTIC during IPY, we adapted piloted, taught, assessed and disseminated several interdisciplinary courses that met the SENCER goals of active learning in a complex and contested place-based, real-world context. For example, we challenged our students to understand how the past legacy of informed development regarding nuclear testing in Alaska led to involvement and stewardship by Alaska Natives as a means of advancing public policy. With this challenge we encouraged the development of responsible citizenry today. Given the current politically-charged atmosphere that surrounds science, our students stand to benefit from a better understanding of both the role of science in policy and the role of policy in science. A place-based understanding of the scientific method and its attendant uncertainty underlie the capacity of our citizens to make well informed choices, and see how their community's world view is integrated in the way science works (Figure 3, Barnhardt and Kawagley, 2008).

Interdisciplinary classes where the scientific issues behind real world situations are considered in a cross-cultural context provide an ideal environment to learn the process for informed decision making. This approach as judged by the SALG outcomes assessment revealed that students demonstrated abilities beyond mastering technical knowledge. They experienced that science is a process of asking and answering questions in order to develop solutions to real world problems. As one student pondered what “big questions” remained at the end of the course, he remarked, “big questions that I still have? Most of it concentrates on “what if” scenarios—what if global warming really does have as large of an effect as many researchers are predicting it will—what will happen then?”

The First Steps: Adapt and Adopt

The term “adapt and adopt” has been used informally for spreading best practices after modification based on context (Boylan, 2004). In the Arctic, adaption and adoption efforts illustrated an effort by educators to include input from the community as well as maintain currency in the scientific concepts. Adoption of ideas, curriculum and individual courses indicate that the reform is meeting a need at some level related to the education and learning of students and citizens: departmental, institutional or even societal. Broader science literacy is bound to benefit society (Caroll and Raber, 2005; Bonney, et al, 2009). Local, regional and global challenges facing the Arctic are connected to the ways in which people consume resources and produce waste and view our relationship to the earth (Duffy, 2001; 2010). But adopting a textbook or course is not enough; it must be adapted, that is, modified for the place where the students live and work. This process of adaptation to the Arctic context in the north can be seen in course evolution from the local traditional ecological knowledge common to Native Science (Cjete, 1999) to a nuclear science course and then into a Land and Environment course. A general non-science majors chemistry course at the University of Alaska Fairbanks (UAF) was improved by adding a SENCERized, traditional knowledge aspect to issues of climate change, energy and water resources.

The course “Radioactivity in the North” at UAF began by adapting/adopting one of the SENCER Model Courses (Middlecamp and Baldwin, 2008). In SENCER courses it is important that instructors make the connections between science, people, and society more transparent, and invite students to engage in the complex social issues that face us today locally, regionally, and globally. If anything, the authors of this paper would argue that issues such as climate change, energy production, sustainable use of resources, and waste reduction are some of today's most relevant issues, especially to minority communities (Trainor et al, 2009). Currently, over 20 SENCER model courses exist, and each provides potential adapters to the Arctic contextual issues with a syllabus, learning goals, and assessment tools. Many of these courses focus on contemporary place based issues of interest to the community and minority world views and perspectives can easily be added. SENCER, with its roots in the “extension service” model of practical education and American pragmatism, extends the importance of learning to the broader community.

As a concrete example, the SENCER model course, “Environmental Chemistry and Ethnicity” (subtitle of “Uranium and American Indians”) was first co-taught in 2002 at the University of Wisconsin-Madison by one of the authors of this paper (CM) and Omie Baldwin. The course used the story of the Navajo uranium miners to illustrate the complex relationships between a cultural group and the development of radioactive technology in the United States. A later revision teaches the story of the radium dial painters in the 1920s and the story of nuclear testing in Alaska in the 1950s to illustrate these same relationships. The Radioactive in the North course at UAF, similarly, teaches the complex relationships between people and radioactivity in the context of the Arctic (Duffy, et. al, 2009). Since teaching science has often been an individual enterprise, without the benefit of knowledge of other instructors’ classroom experience or the current cognitive science research results on how students learn, adaptation was “hit and miss” relearning what other instructors already

discovered. To avoid this problem, an adaptation team was formed which included the instructor and graduate students, an evaluator and consultant.

Realistically, course development is constrained by the time and energy available from the instructors. The fact that we could adapt and adopt from an existing course greatly facilitated the course development process, especially in establishing learning goals (Table 1). Learning goals should drive the development of any new course. Once in hand, these goals can be mapped into the course activities, learning assessments, and any evaluation tools needed for external constituencies. As Barbara Tewksbury (2008) points out each year at the SENCER Summer Institutes, “SENCER as a program is strongly goals-based and less focused on “coverage” than is typical for courses.” One of the strengths of the SENCER project is the emphasis this approach places on higher order learning goals. SENCER model courses, including the one from which Radioactivity in the North was adapted, lists higher order goals for the students. In the process of course development, we worked to avoid the “content trap” that is, designing a course based on what content we thought we would “cover.” Rather, we thought first about higher order learning goals for student learning and reverse engineered the course in the light of the goals set as summarized in Table 2. Since these goals were congruent with the model course, Uranium and American Indian (Middlecamp et al, 2006), the adapt and adopt process occurred smoothly for course modification. As noted in Table 1, a higher order goal is the integration of cultural and scientific issues. The indigenous (or minority) culture world view needs to be explicitly illustrated in the course, and discussed as illustrated by the “Seven Generation Perspective” when discussing water usage and contamination (Table 3).

The course, Radioactivity in the North, took these general goals and developed an Alaskan and Arctic context for nuclear science. The basic nuclear science concepts were standard, but the Arctic cultures, world views and contexts of the discussion moved to central position in the presentation. Accordingly, articles and books relating to radioactivity in the north as well as speakers were integrated in a more holistic presentation. Structural elements included class activities, grading rubrics, and the use of the Student Assessment of Learning Goals (SALG) for student course evaluation were also added to fit the SENCER model. The assignments evolved to include either a book report or a community learning component, although students did not use this often. The first option allows students to follow up and report on a personal issue of interest; the latter gives students an opportunity to apply what they learn in the context of a local organization dealing with a relevant local issue. Learning outcomes and student assessment of the course were very good. For example, “[this] is the best course I have taken at this university for many reasons – the ability to successfully integrate science and the issues surrounding it being just one of many.” These lines were excerpted from a longer piece by a student in her final reflection piece for the course. Even the dissatisfaction expressed by another student took a positive spin: “Most of my complaints would revolve around not learning enough – every issue seemed interesting enough to have an entire class about.” Similarly, other students reflected positively on their learning experiences. In the context of real-world issues, another student reported: “... *my understanding has broadened.*” Another student exclaimed: “*The subject is fascinating!*”; another quipped: “For oddities in the University of Alaska System, we were definitely top of the list. Interdisciplinary courses are a refreshing place to learn, ...”Educators who have been

through the process of designing a new course know that student assessment is an important factor that helps determine the success of a course, especially an elective. These results support Sobel's observation (2004) that by using place and environment, a framework is created which helps students construct their own learning.

In the development of this upper level course we learned that adapting and adopting a previously existing course has practical limits. Most importantly, to be of use, the match between the model and the new course must be reasonably close. The instructor must adapt and adopt from the model course judiciously, carefully tailoring the new course to meet the demands and context of its new, place-based environment (Table 2).

In regards to continuity, that is, how the course will fare over the years to come. It is important to find the right program, department, or college in which to house the new course, as it needs to mesh well with the mission and vision of its curriculum home. Since Arctic research is very interdisciplinary, a department or school with a faculty that values a team approach across disciplines would be a good fit for UARCTIC or SENCER courses. How a new course reflects the realities both of our changing disciplines and (ultimately) of our changing planet is based on the need to prepare our students for the challenges not only of today, but also those likely to arise tomorrow.

Given the politically-charged atmosphere that surrounds the use of nuclear energy and uranium mining in Alaska, the students benefited from a better understanding of how attitudes changed in Alaska and how the indigenous voice was ignored by the Lower 48 (O'Neil 2006; Burger, et al, 2007). No matter the students' major or culture, SENCERizing worked for this course.

Chemistry in Complex Systems

A general science course for non-science majors was adapted and improved by focusing on chemistry in Alaska and related cultural and political issues. While special topic interdisciplinary classes on the science behind real world situations with a traditional knowledge component can be placed quickly before the students, integrating indigenous world views into relatively standard general science courses is more difficult. In the past, the need to correct this led to the UARCTIC approach of developing a circumpolar studies program. One solution was the UARCTIC's circumvention of the state university's curriculum by establishing a "Circumpolar Studies Major". However, despite growth in students enrolled in the UARCTIC BCS, this approach misses a great number of traditional university students who would benefit from exposure to an indigenous perspective.

Universities need to teach all students the role of basic chemical and biochemical sciences as they function within the context of complex natural systems. Chemistry and biochemistry are central to the world around us and it is not that difficult to understand them or their importance to our social and economic systems, although the faculty members have to learn about these systems. Chem 100, Chemistry in Complex Systems, was designed to engage students in the issues affecting the world and Alaska. Exposure to the chemical science associated with these issues was enhanced with the integration of traditional knowledge and

cultural practices. The perspective of cultures that have enabled people to survive in this extreme natural system enhances its value to science.

The overall objectives of Chem 100 were to provide each student with a basic literacy of some chemical and biochemical principles, an appreciation of how chemistry pervades complex systems, some historical aspects of its concept development, an ability to understand some of the scientific issues which confront us as citizens, and an appreciation of how, and the extent to which, science is able to solve our problems (or create them). We adapted this already SENCERized course and its text book "Chemistry in Context" by adding a place-based and traditional knowledge perspective.

The course's specific goals for students were to become familiar with 1) the methods and ethics of science used by chemists and biochemists, 2) the role of uncertainty, hypothesis testing, and weight of evidence in environmental issues, 3) major concepts of chemistry such as conservation of matter, chemical reactions, pH, air pollution, etc.; 4) an appreciation of the science in traditional knowledge systems; 5) demonstrate how the scientific method and design works in relation to policy. Running through the course as consistent themes are the impacts of water and air pollution on the north as well as Alaskan and global connections with the inclusion of the indigenous perspective of stewardship and precaution (Trainor et al, 2009; Godduhn and Duffy, 2003). Water and ice are a major component of indigenous traditional ecological knowledge in the North (Ingram, et al, 2009; Krupnik and Jolly, 2002). Water, its necessity and growing demands, are interconnected with the chemistry basic to living systems while resource development is connected to stewardship. Natural products, drugs and the contamination of subsistence foods are other topics in which the indigenous perspective was introduced for discussion. Energy and biofuels are connected to global warming and climate change (Table 3).

As Table 3 illustrates, we have included a culture/traditional knowledge component to Chem. 100, Chemistry in Complex Systems. In our adaptation, the chemistry is embedded in the exploration of social policy issues as part of the textbook, "Chemistry in Context" (Schwartz et al, 1994), but the engagement for the indigenous student is enhanced by the cultural related place based discussion of the science. The organizing principle of the course is real-world issues but from an indigenous perspective. The instructional pathway is from the global real-world into the discipline of chemistry into place based cultural relevance. Since the textbook content is inherently interdisciplinary, the approach fits well with the indigenous holistic world view. Many indigenous groups teach Native Science (Cjete, 1999) by using the story or metaphor which fits well with real world issues. The real world is not separated in an arbitrary way as are scientific disciplines and fields. Global climate change is a good example of using a real world issue that impacts indigenous people in the north ((Middlecamp, 2008).

The structural elements of the course were adapted practically wholesale from the textbook "Chemistry in Context". The SENCER elements included the use of Student Assessment of Learning Goals (SALG) for student course assessment. The assignments were modified to include either a book report or a service learning component that could replace a lab. The first option allows students to follow up and report on a personal issue of interest; the latter

gives students an opportunity to apply what they learn in the context of a local organization dealing with relevant issues. The integration of traditional ecological knowledge with other content promotes discussions from all students but for the first time in the instructor's experience, Alaska Natives voiced the views of their elders.

Land and Environment

The UARCTIC Land and Environment course provides students with a greater understanding of the complexity and relevance of Arctic issues. This class is an ideal forum to promote integrative thinking. The students are highly diverse in experience, education, and geography, making cross cultural communication an intrinsic component of the coursework. The discussion generated by asking students to relate the assigned readings to their own experience and community is lively, interesting and informative for everyone, including the teacher.

The course deals with the impacts of natural and physical change on the peoples and complexity conditions of the circumpolar north and, especially in the second term, concentrates on three major fields for scientific study: 1) climate change and complexity; 2) natural resources and 3) health and environment. Emphasis is given to the challenges of sustainability in the North and to the need for proper long-term stewardship. The course is conceptually similar to Chemistry and Context, but is targeted at advanced students. The goals and learning outcomes are:

1. A more in depth chemical and biological knowledge of the general concepts underlying selected natural resources.
2. An appreciation of how scientific methods contribute to the understanding of resource management and human health .
3. Insight into the complexity of environmental and human systems, and the effects of change on northern ecosystems.
4. An interdisciplinary understanding of relationships between cultures of the north, stewardship values and scientific knowledge.

This course was developed both for the UARCTIC place-based Circumpolar Studies curriculum and as a UAF Liberal Arts and Sciences (LAS) elective. The course was designed for web based delivery and consists of twelve modules; each comprised of a "lecture", additional required and suggested readings, student activities, and study questions (Table 4). Students discuss the module text in the online discussion groups each week. Although the course is global in nature, English is the principal language used, with consideration and assistance for those whose first language is not English. This course is part of the "science core" for the UARCTIC BCS program (www.UARCTIC.org).

The need for a place based interdisciplinary science course in the BCS curriculum is crucial in light of climate change and the North's vulnerability. The importance of understanding the science and related policy issues for the circumpolar north increases at a time when humans are influencing biogeochemical cycles of the north through increased resource development and extraction, and the aggressive harvesting from the marine food web. As a unique

component of the global environment, the circumpolar north, with large seasonal changes in light and temperature, is pivotal as a region sensitive to change and as a driver of change in other parts of the world. Recent experience shows that the Arctic has a predisposition to deliver environmental surprises, such as the abruptness of change. Complex environmental system theory suggests that the emergent properties, generated by multiple feedback systems, in the Arctic system may be different than at lower latitudes. Scaling and temporal history are also different at higher latitudes and have only recently begun to be studied. The non-intrusive connections between global and arctic systems may put circumpolar peoples at greater risk and this risk must be addressed by policy.

Many northern indigenous populations are exposed to elevated concentrations of contaminants through traditional food and many of these contaminants come from regions outside the Arctic (Godduhn and Duffy, 2003; Kraemer et al, 2005; Dunlap et al, 2008; Ingram et al, 2008). Global contaminant pathways include the atmosphere, ocean currents, river outflow, and animal migration, all of which are affected by climate. In addition to these pathways, precipitation, animal availability, UV radiation, cryosphere degradation and human industrial activities in the North are also affected by climate change. The processes governing contaminant behavior in a changing environment are complex and therefore, in order to understand how climate change will affect the health of northern people, we must have a better understanding of the processes that influence the Arctic environment (Duffy, 2010). But research alone is of little value unless it is disseminated to people who need the information to live. The goal of “Land and Environment” is to educate by integrating generalized science concepts with place-based knowledge that helps the students to understand what is occurring around them. This will enable the student/citizen to join the socio-political discussion that is occurring in the north. “Land and Environment” creates a framework that cuts across various scales of time, size and geography. One student wrote,

My impression of the North has changed in such a strong way that I feel the need to do whatever I can to ensure that the remaining fragile habitats are protected for the future generations of people that will [be] enjoying the benefits from the natural resources. Some of the important traditional ideas that were confirmed by scientific facts are quite interesting. I truly appreciate the contribution that the Elders made in answering the many questions that I asked them. The main question that still lingers in my mind is When are there going to be some type of hard law principles established for the Arctic?

I have truly enjoyed this class and much of the material will be a definite asset for myself and the people in my region. My fellow students have provided some very valuable insights in the discussion forums. Good luck to all and have a nice summer.

Beyond the UARCTIC goal of access and sharing of knowledge among northerners, Land and Environment met the IPY goal of educating those from outside the region as the following quote illustrates.

...during this course I have really enjoyed putting names and facts to the body of arctic information I have learned previously. My impression of the North; since I was a lot younger has been of a mystical and magical place, and every class I take

specifically on the Arctic serves to both strengthen and broaden that view. Robert McGhee says the North is “the Last Imaginary Place”, and as a southerner I’m still trying to (and am not sure I ever will) fully grasp the true sense of it being a ‘Home’. This course has however taught me that it is home, to not just people and plants but an array of natural wonders seen nowhere else on earth.

Challenges

To be successful, a new course must generate and maintain enrollment. As they say in real estate, it is a matter of “location, location, location”. Both the home department of the course and its wider role in the whole university’s curriculum need to be considered. More specifically, factors to consider in marketing *any* new course include: (1) finding a department and course number, (2) providing an incentive for students to enroll, (3) overcoming any logistical obstacles, such as conflicts with other required courses, and ultimately (4) establishing a positive track record on campus with advisors and students. Relevant to these particular courses was the goal to attract Alaska Native students and engage them in science. The instructors have yet to find an approach that has brought the desired on-going enrollment in the UAF special topics courses; however enrollment in the Land and Environment and Chemistry in Complex Systems courses have steadily grown each year.

In the case of Radioactivity in the North, the first semester (Fall 2007), the class was offered as an upper level Liberal Arts and Science (LAS) class as part of the UAF Honors program. Only four students enrolled. The next semester the course was more heavily marketed, with a full page insert in the university’s student newspaper and posters that advertised the course. The course was also cross-listed between the department of Chemistry and Biochemistry and the Department of Anthropology, maintaining the Liberal Arts and Sciences (LAS) designator, but enrollment did not improve (Duffy, et al 2009).

Another change is the course must fit within the context of the existing university disciplinary system, especially in regard to course pre-requisites and requirements. In the next attempt to offer the course, the instructor noted a new problem of pre-requisites for an interdisciplinary course appeared within the chemistry department as its leadership changed. Some current faculty members hold the view that a chemistry course with a chemistry designator must require the introductory general chemistry course as a prerequisite. But this prerequisite excludes “non-chemistry” students from enrolling in “Radioactivity in the North”. Ironically, these are the students who have made possible the spirited interdisciplinary discussions and debates between science and non-science majors. The problem of generating enrollment remains for this course. Without being a required course for graduation, either as part of general education such as Chem 100 or as part of a major, students are far less likely to elect to take it. In addition, by being an honors course, this course may inadvertently appear more exclusive or perhaps even intimidating to the very students we hoped would take the course; namely Alaska native students. Currently we are exploring teaching this course as “writing intensive”. Since a certain number of “W” classes are required at UAF, this could provide a local incentive for taking this elective class.

Ultimately, the ability of a course to fit within an institution's curriculum is the key element of any “adapt and adopt” initiative. Even though experience with the “Radioactivity in the North” course indicates that the students will have a highly positive learning experience, the course cannot be maintained in a state university's departmental curriculum without sufficient enrollment. However, the popularity of “Chemistry in Complex Systems” and “Land and Environment” demonstrates that enrollment solutions are possible.

Enrollment issues aside, the SENCERization demands instructor creativity and flexibility. Instructors may have to change their teaching style to better integrate story telling and cultural relevance. Perhaps more difficult, instructors must be willing to expose their lack of knowledge regarding the chemical or social concepts associated with topics such as climate change, nuclear waste or water. For example, they may not know which gases do (and do not) come out of the tailpipe of a car. Instructors will have a learning curve right along with their students. An instructor must invest time in learning new content and in maintaining current knowledge with interdisciplinary scientific developments. The need-to-know basis that drives the selection of chemical content presents a related challenge for instructors. If a need-to-know does not exist for a topic, it will not appear in the course. This scenario may require instructors to let go of teaching one or more long-held favorite topics and/or to teach these topics in far less depth.

An instructor must invest time in learning new content and in keeping current with interdisciplinary scientific developments. The topics of global climate change and nuclear energy are good cases in point. Still another challenge is that instructors may need to change their instructional practices to better meet the story telling approach, including new goals such as cultural relevance. At state universities, it is a challenge to meet the needs of all students when the enrolled students have a diverse background of knowledge, skills and abilities. This is in addition to the diversity in world views that we have been discussing (Kawagley et al, 1998; Cjete, 1999).

Discussion

Thus, the urgent need for informed citizens lay at the heart of our efforts at course reform, as well as for the larger SENCER curriculum reform initiative. We know that we need to design general and specific topic science courses that can enroll and engage a wide range of students (NAS, 1996; 2003). For example, chemistry by its nature is about making chemical products and processes to make them better and more efficient. Sustainability is inherent in chemistry. But a more focused and guided effort is needed to create the energy, safe drinking water, adequate food, housing, transportation, and medical care that we want to live meaningful, comfortable and healthy lives –not just for the current generation of humanity, but in perpetuity. The workforce, both chemists and other personnel need to have a perception that science is an aid to sustainability and stewardship (Duffy, 2001). Both these concepts are intrinsic to indigenous world views and should be emphasized in our science courses. We must transform our educational approach by being inclusive of minority values and world views. Place-based SENCERized courses are a means of putting the complexity and diversity of real world issues before the student for consideration.

The adapt and adopt process is synergistic, with both parties benefiting from each stage of the collaboration. Creating a new course using an existing one as a model can improve and speed the process. With each issue come choices; and each choice carries ramifications that affect the success of the course.

The process of creating a course also contains intellectual challenges. In the process of working together, both parties were forced out of their comfort zones to examine both existing practices, to critique each one, and in some cases to create new ones. Our goal was to adapt and adopt existing course materials to accomplish a task of value to all.

The convergence of advances in science and the science of learning comes as Arctic peoples are faced with significant challenges from climate change, resource development and food security—challenges that cross disciplinary boundaries. In the science of learning research, results enable faculty to more effectively introduce and engage students in the science related to these complex problems. The SENCER approach allows Arctic educators to convey the wonder of the north along with the curiosity for science that encourages thinking, not just content memorization. By including different world views, instructors and students can look beyond existing textbooks to a new synthesis of science with varied cultures. These courses lead students to develop critical thinking skills that are rooted and functional in their communities. Place-based knowledge is retained because it is revisited every day. Our experience is that students enter these courses believing they already know the subject but after viewing the content from different perspectives, they report an increase in understanding. Both how and where you study a subject has great impact on retention and functional use.

Indigenous world views with their holistic vision of nature, including man, allows scientists and students a chance to see how society views them and what they value (Duffy, 2010). Indigenous cultures allow art as an interpreter of science to convey both the content and process. Art and science were once strongly intertwined because observational data and experimental setups could only be rendered by hand. This connection has gradually languished in the modern, non-indigenous society (Duffy, 2010). The indigenous holistic approach, however, leads the researcher, instructor and student to examine and think about a topic from different perspectives and scales. This was a valuable learning tool as students in Radioactivity in the North followed the way artists and journalists portrayed the growth of the atomic age and nuclear energy.

Conclusion

Where you live should have something to do with what you teach. In the Arctic, this idea of place-based education—teaching and sharing knowledge that is needed to live well—is central to the UARCTIC consortium and the 4th International Polar Year educational reform effort. A place-based issue oriented context can engage students in chemistry concepts when it intersects with their experience and world view. The local landscape should be central to science courses and involve issues relevant to stewardship, a component of the indigenous world view. Curriculum reform that focuses on real-world topics engages students so that

they perform well in class but also sparks their interest so that they continue learning after the course is over.

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Figure 1.
An illustration of the connectivity of the IPY projects. The UARCTIC coordinated interaction of the education with the research efforts. This figure also illustrates one of the many dissemination events that occurred during IPY.

Figure 2.
Outline of the UARCTIC BCS Program

Figure 3.
Integration of Traditional Knowledge with Western Science/Neuroscience (Adapted from Barnhardt and Kawagley, 2006)

Figure 4.
The Indigenous perspective of climate change: connection to chemistry, (Adapted from Middlecamp, 2008)

Figure 5.
Industrial chemicals can impact food security for subsistence users

Table 1

Goals for the model SENCER course, “Uranium and American Indians”

<p>In this course, we hope you will acquire a deep understanding of the radioactive substances on our planet. This includes your ability to:</p> <ul style="list-style-type: none"> • Know where one would expect to find radioactive substances on our planet. • Categorize radioactive substances on our planet as primordial, continuously replenished naturally, or human- made. • Use the concept of half-life to estimate when a radioactive substance will be “gone”. • By the context, interpret the term “radiation” as either nuclear (ionizing) or electromagnetic (either non-ionizing or ionizing). • List different types of ionizing radiation (alpha/beta particles, gamma rays, X-rays) and compare them by mass, charge, and ability to penetrate. • Given a radioisotope such as radium-226, cobalt-60, iodine-131, polonium-210, plutonium-240, or radon-222, being able to assess its health hazards (if any) based on factors such as the amount present, chemical behavior, physical form, half-life, type of radiation it emits, and route of uptake (or not) into the body. • [others omitted...] <p>But please <u>think beyond covering scientific content</u>. This content is secondary to a set of higher order goals. These include your ability to:</p> <ul style="list-style-type: none"> • Integrate cultural and scientific issues. • Formulate questions about complex topics that interconnect people and science. • Handle complex ideas that do not have a single or best solution to all concerned. • Communicate technical scientific ideas to the general public, both in essay form and by drawing up “talking points.” • Learn something in one context and apply to another. • Engage others in learning about a topic that is important to you. • Take an informed stand on a controversial topic and be able to articulate your point of view to others. • Review another person's work/performance_and offer helpful feedback. • Review your own work, consider the feedback of others, and make appropriate changes.

Table 2**Course Philosophy and Objectives for the new course, “Radioactivity in the North”**

Our philosophy is one of integration: science, policy, and culture in the circumpolar north! To achieve scientific literacy, students must come to understand key concepts and work through challenging problems of “traditional” chemistry. Since science occurs within systems of culture, economy, and policy, we believe that students also should consider the context and linkages of scientific research, knowledge development, and stakeholders’ interests. Successful students will be able to apply what they have learned to new situations, frame useful questions about related issues, and communicate effectively.

Students will learn how nuclear chemistry and biomedical science are relevant to the lives of people in the North, including Alaska Natives and rural circumpolar people. Complex societal issues will be central both to the storyline of the course and to the intellectual tasks required of the students taking this approach.

We want you to ...

- appreciate how culture pervades complex systems, participating in positive and negative feedback loops with policy;
- gain an essential understanding of nuclear chemistry, biochemical responses, and related health research;
- become familiar with and be able to discuss the methods and ethical frameworks used by scientists and engineers;
- evaluate the scientific basis of nuclear policy concepts, and the relevance to societal decisions;
- learn about historical events in the north and consider the role of this history and Alaska Native culture in environmental and nuclear issues;
- know what questions to ask and how to predict potential hazards when you are given a scenario involving a particular radioactive substance or an issue such as the proposed “nuclear battery” in Galena, Alaska; and
- think about how, and to what extent, the science nuclear energy and weapons development is able to solve our problems—or create them—using the north as the context.

Table 3

Lecture plan for Chemistry in Complex Systems

Week	Title	Chapter	Historical	Societal	Culture
1	Scientific Method	0	Cisplatin Vitamin C	Technology	Alaska Native Knowledge
2	States of Matter, Elements	1	Lavoiser	Air Pollution	Impacts of Mining
3	Periodic Table, Molecules, Reactions	1	Burning	Dalton's Theory	Impacts of Burning
4	Atomic Structure, Lewis Structure, Chapman Cycle	2	Chapman	Pollution Policy	GAIA
5	Molecular Shape, Carbon Cycle, Trophic Levels	3	CFC POPS	Carbon Dioxide Policy	Arctic Council and AMAP
6	Greenhouse Gases/Mass/Moles	3	IPY		Global Transport
7	Energy, Coal, Petroleum	4	Fossil Fuels	Climate Energy Era	Ecosystems Impact and Native Science
8	Water, Intermolecule Forces	5	Linus Pauling	Water Quality	Ice and its Names in the North
9	PH, Acid Rain	6	Coal	Environmental Justice	Seven Generations
10	Carbon	10	Aspirin	Biotech	Nature Medicine
11	Drugs	10	Natural Products	FDA	Birch Trees
12	Steroids	10	Lipids	Human Enhancement	Diabetes
13	Nutrition, Lipids Carbohydrates, Proteins	11 11	Global Food Systems Proteins	Obesity Food Pyramids	Food Preservation Caribou Gut Products
14	DNA	12	Watson	Profiling	Origins
15	Genetic Engineering	12	Dolly	Cloning	Identity

Table 4

Land and Environment Course Topics

Part I	Climate Change and Complexity
Week 1	Module 1: Frameworks for Analysis of Land and environment in the Arctic Read the syllabus and become familiar with the website Read the module text and post a comment in the week's discussion forum
Week 2	Module 2: Biocomplexity in the North Read the module text and post a comment in discussion forum
Week 3	Module 3: Fisheries Read the module text and post a comment in the discussion forum
Week 4	Module 4: Marine Mammals and Fisheries 1 Read the module text; essay assignment due at the end of week 4.
Part II	Natural Resources
Week 5	Module 5: Natural Resources: Chemistry and Environmental Sustainability Read the module text and post a comment in the discussion forum
Week 6	Module 6: Water Supply and Waste Treatment in the Arctic Read the module text and post a comment in the discussion forum
Week 7	Module 7: Observations, sustainability and the Impacts of Change Read the module text and post a comment in the discussion forum
Week 8	Module 8: Food Chemistry, Subsistence Webs and Nutrition Read the module text and post a comment in the discussion forum; written assignment due at the end of week 8.
Part III	Health and Environment
Week 9	Module 9: Diet and Mental Health of Circumpolar Peoples Read the module text and post a comment in the discussion forum
Week 10	Module 10: food Traditions and Food Systems in Rural Alaska Read the module text and post a comment in the discussion forum
Week 11	Module 11: Nuclear Chemistry, Radioecology and Stewardship Read the module text and post a comment in the discussion forum
Week 12	Module 12: Cancer and Biomarkers of Health Read the module text and post a comment in the discussion forum