HHS Public Access
Author manuscript
ACS Symp Ser Am Chem Soc. Author manuscript; available in PMC 2019 September 18.

Published in final edited form as:
ACS Symp Ser Am Chem Soc. 2018 ; 1276: 1–19. doi:10.1021/bk-2018-1276.ch001.

Introduction to Environmental Chemistry of the Arctic: An Introductory, Lab-Based Course Offered Both Face-to-Face and by Distance

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Abstract

In this chapter, we present a model for an entry-level lab-based undergraduate environmental chemistry course delivered simultaneously by face-to-face and distance modalities. This course frames conceptual chemistry using the theme of Alaskan Arctic environmental issues in order to increase engagement and perceived relevance of chemical principles. Synchronously delivered lectures and guided discussions along with the incorporation of peer-mentored research projects encourage the development of a learning community among students in the course. Distance students participate in the same virtual and “kitchen” lab experiments as on-campus students, thus providing an educationally equivalent curriculum to all. In mixed teams of on-campus and distance students, all students participate in research projects to allow entry-level students to explore their interests in STEM fields. Students thereby begin to build an identity as a scientist and hopefully this course will serve as a mechanism to improve recruitment and retention of students, especially from traditionally underrepresented groups, in the chemical sciences and other STEM fields of study. Responses from the first course offering communicated positive attitudes toward the course content and methods.

Introduction

Alaska and the Arctic: A Contextually Relevant Framework for Environmental Chemistry

Environmental chemistry has been increasingly introduced into undergraduate curricula in recent decades (e.g., (1–4)). Contextually driven activities improve both understanding and engagement in undergraduate courses by highlighting the relevance of chemistry and its application to the real world (4). Environmental chemistry is an especially useful context in which to present chemical concepts, especially for non-majors (3). Incorporating environmental and climate-change issues into chemistry courses has been shown to improve scientific literacy and conceptual understanding (5, 6).

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High-latitude systems are especially sensitive to changes in climate. The Arctic has continued to see air temperatures increasing at double the global average rate, bringing with them a host of environmental changes from decreases in sea-ice extent to thawing permafrost (7). Alaska represents a diverse set of ecosystems from coastal Western hemlock-Sitka spruce forests to the treeless Arctic plains (8). Wetlands cover an extraordinarily high proportion of Alaska, occupying 43% of Alaska’s surface area compared to only around 5% of land surface area in the lower 48 states (9). The fate and transport of contaminants in the Arctic is also of concern, as organic contaminants have been observed to undergo long-range transport to high latitudes (10). Thus, assessing surface water quality is critically important for understanding Alaska’s environmental health.

This is especially true in rural communities, where residents live in close connection to and rely upon their environment. Environmental stresses affect subsistence practices, food availability, water quality, and infrastructure, among many other aspects of life (11–15). Many Alaskans connect with the One Health paradigm, i.e. the idea that the health of humans, animals, and the environment are inextricably linked (13, 16, 17). As such, Alaska and the Arctic are an ideal backdrop against which to highlight environmental chemical processes in atmospheric, aquatic, terrestrial, and biological spheres, in addition to being directly relevant to communities within the state.

Course-Based Undergraduate Research and Peer Mentoring

The demonstrated benefits of incorporating research into course curricula are well known (e.g., (18)), suggesting that research not only affects attitudes toward the relevance of chemistry (5), but also improves confidence, understanding, and success in later courses (19–22). Undergraduate involvement in research has also been linked to improved critical thinking, intellectual independence, and increased retention in fields related to STEM (23).

Mentoring has specifically been observed to improve the student research experiences and retention of students from traditionally underrepresented groups (24, 25). Mentored research early in the undergraduate experience, particularly that which blends both faculty and near-peer mentoring, can be an effective method for integrating students into the research process (e.g., (26, 27)). Effective mentoring has been linked to increased independence and competency (28–31), as well as improved retention (24, 32, 33). Peer mentoring in research contexts, when undergraduates mentor each other, is viewed positively by undergraduates and have benefits including becoming part of a community, growth of self-confidence, and a sense of accomplishment (34). These factors are important for persistence within STEM (35). Further, studies have shown that peer instruction can lead to improved conceptual understanding (36, 37).

While traditional undergraduate research provides many benefits such as those listed above, course-based research is also beneficial to students. Participation in a classroom-based research experience at the introductory level has been linked to positive changes in student interest toward pursuing science careers and attitudes toward science in general (38). Course-based research experiences are also attractive to students because of the finite time commitment required (39). Course-based research experiences have been shown to provide several benefits that promote inclusion, that may be especially important for traditionally

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underrepresented students, including: improving awareness of research opportunities, learning of the benefits of research, and providing interactions with faculty (40). Together, these benefits may serve as a gateway to future more traditional undergraduate research experiences.

Engagement Challenges with Distance Learning

Course-based research is an example of integrating active learning techniques in the classroom, and has been shown to statistically improve student grades, long term comprehension (41, 42), and reduce the achievement gap between disadvantaged students and their peers (43). These techniques are supported by pedagogical studies that have concluded that classroom lecture learning accounts for less than 10% of the lifetime learning (44). The effectiveness of a variety of active learning techniques has been demonstrated, including: case studies, student discussions, lecture pauses, and involving students as creators. However, incorporating active learning techniques in distance courses can be especially challenging.

This Study

The authors developed a blended face-to-face and distance lecture and lab-based course that interweaves Alaska and Arctic-relevant issues throughout the curriculum, emphasizing chemical principles and their roles in the environment. This course incorporates active learning in several forms as well as faculty-directed and peer-mentored research projects. In keeping with best practices (45), the curriculum deliberately integrates the face-to-face and distance courses by mixing student teams to facilitate the development of learning relationships between students. We have intentionally designed an environmental chemistry course that involves students as both researchers and peer mentors to strengthen the sense of a learning community among participants. This course engages students in all aspects of the research cycle, including: developing laboratory techniques, applying the scientific method, making and recording careful observations, interpreting numerical data, and sharing their results. Thus, entry-level students learn introductory chemical concepts by engaging in faculty-directed research and exploring the status of environmental health in Arctic ecosystems and communities.

Rationale

In this chapter, we describe a model for a lab-based course offered simultaneously by on-campus and distance modalities in which chemistry is taught in the context of Arctic environmental health. The target demographics are early career or nontraditional undergraduate students regardless of their physical location within Alaska or declared major of study. As a core-designated course, this course is accessible and attractive to students from diverse majors of study and will hopefully serve as a mechanism to build science literacy across the state.

Distance learning is a particularly important method of instruction for Alaska because, being the largest state in the United States, it has many rural communities that are separated by large distances and not connected by roads (Figure 1). In 2000, Alaska had less than 13,000

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miles of public road (46). In fact, several unique factors can impact the student experience at distance campuses or in rural communities in Alaska compared to most locations in the rest of the U.S. These include: limited bandwidth for internet connectivity, below freezing temperatures for most of the academic year, and most outlying communities are not connected to the road system, meaning materials have to be transported either by water during the summer or by air. All of these factors must be taken into account when planning a successful lab and field-based distance course like the one described here.

The University of Alaska system has a high proportion of non-traditional and rural students. It is common for students to take courses online, though there are currently few offerings in chemistry or that incorporate research, and few undergraduate environmental chemistry courses (distance or face-to-face), especially targeting early undergraduates. This was seen as a great opportunity to make chemistry relevant for our students by applying it to the Arctic environment where they live and capitalizing on faculty research expertise. This course was designed to attract students early in their post-secondary education in order to provide a course-based lab and peer-mentored research experience by distance, in hopes of improving STEM recruitment and retention.

Students are expected to come to this course with no previous research experience. They are guided through small but highly relevant research projects examining surface waters from their home communities. The project portion is intentionally designed to involve students as both researchers and peer mentors (Figure 2). In cooperation with other members of their research teams (which are ideally mixed between face-to-face and distance students), students examine water quality indicators within the context of human, animal, and ecosystem health. In this way, we are directly incorporating One Health relevant research into the curriculum in a way that is accessible to students with little prior science knowledge.

We hope to recruit or retain nontraditional STEM majors, who might not be as successful starting off in a more traditional, calculation-based general chemistry setting. Applying conceptual chemistry in the context of Arctic environmental health is aimed to frame the content in an especially relevant and accessible format for rural Alaskans. Engaging students in research empowers them to assess the health of their home communities. Further, building personal relationships between rural students and the main University of Alaska Fairbanks (UAF) campus could support rural students interested in finishing their degree program at UAF.

Degree requirements include core courses, which are designed to provide "*students with a shared foundation of skills and knowledge that, when combined with specialized study in the major and other specific degree requirements, prepares students to better meet the demands of life in the 21st century*" (47). These core requirements include eight credits of natural science, which are fulfilled by taking two specially designated lab-based courses selected from the 100 and 200-level science classes.

Enrollments were capped such that there was a limit of twice as many face-to-face students as distance students, to best facilitate the integrated group research projects with mixed teams of distance and on-campus students. The ratio of distance to face-to-face students with

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regards to this course and student success has not yet been thoroughly tested, and are open to adjustment in the future depending on the composition of the research groups in future deliveries.

Student Learning Outcomes

This course was intentionally designed to require less advanced math prerequisites compared to that required by most STEM core courses at UAF, in order to reach students early in their post-secondary experience and remove barriers for exposure to the chemical sciences. Taken directly from the syllabus (48), after successful completion of this course, students will be able to:

1. Understand the basic chemical concepts as they relate to the function of ecosystems and the existence/transformation of contaminants.
2. Outline basic metrics for assessing air, water, and soil quality and explain their importance as indicators of environmental health.
3. Identify examples of anthropogenic influences of natural cycles and explain how that impacts ecosystem health.
4. Evaluate student-generated water quality data from across the state and interpret data to assess anthropogenic perturbation of ecosystems.

Each of these student learning outcomes were integrated throughout the entire course, through synchronous lecture, discussion, laboratory, and peer-mentored research activities as described below.

Implementation

Successful execution depends on developing strong integration between lab and lecture topics (Table 1), creating lab kits with clear instructions, integrating tablet technologies to create a seamless interface between on-campus and distance students, and supporting teams in forming strong collaborations. The course syllabus is available from the UAF Department of Chemistry and Biochemistry website and a course schedule is shown in Table 1 (48).

Integration of Face-to-Face and Distance Course Delivery

This course was set up for enrollment in either a face-to-face or distance format, each worth the same number of credits and providing equivalent experiences. The lecture was held synchronously with both face-to-face and distance participants, in order to foster productive real-time discussion on course topics, and facilitate the development of a learning community during each class period. While distance courses are often perceived to be less engaging than face-to-face courses, specific strategies were implemented to enhance engagement and facilitate active learning. Both peer-to-peer and instructor-to-peer communication have been reported by students to be the most important factors in facilitating engagement in online courses (49). This is also reflected in the fact that student completion rates in online courses tend to be higher when students perceive a sense of community (50, 51). We chose to enhance this through peer-discussion online, peer-

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mentored research, and faculty facilitated discussion during synchronous class time, along with regular directed feedback between instructor and student relating to coursework.

Lectures were delivered through the university learning management system (LMS), where non-animated slides and audio were transmitted so as to lower the bandwidth requirement for distance students. The software allowed for distance students to raise hands, type questions, and/or speak by audio during the class session, as needed, in order to be fully interactive during the session.

In addition to lecture, all of the other facets of the course were delivered online as much as possible. Reading questions and exams were conducted through the LMS, and all lectures were recorded and posted on the LMS. Lab report forms were filled out either in person for face-to-face students, or scanned/photographed and uploaded into the LMS for distance students. A discussion forum hosted on the LMS was required for all students in order to foster interaction between face-to-face and distance students, which was actively monitored by the instructors.

To ensure distance students had tools necessary for full and engaged participation, android tablets were sent out with the distance laboratory kits on loan. Distance students were responsible for their own internet access, but otherwise the tablets contained all the necessary apps to participate fully in the course pre-loaded onto the device, which then became their portal for the course.

Context-Driven Chemistry

In addition to incorporating Alaska and Arctic specific issues into lectures, several lecture periods included guest lecturers from various departments within the university who offered extpertise in different areas. Guest lecturers were researchers who shared their research and how it related to environmental chemistry, thereby giving students the opportunity to see how scientists were actively using environmental chemistry to solve real-world problems.

Weekly case studies from poplar news or science articles or National Center for Case Study Teaching in Science (NCCSTS; (52)) were chosen for their environmental and/or Arctic themed relevance. These formed the basis for discussion board topics, in which a few discussion prompts were posted each week to facilitate student sharing. Some of the prompts focused on comprehension of the issues, while others focused on student reactions and the impacts students had observed in their home communities. Participating in discussion forums (both posting and replies) was a required part of the course for all students.

Distance and On-Campus Laboratory Experiences

There are several established ways to approach distance laboratory experiences, including: lab intensives, kitchen labs, and virtual labs. Lab intensives are when students travel to a campus for a few days to perform experiments with their classmates, and are most similar to a traditional lab course experience, except with a compressed time frame. This option has been used successfully in rural Alaska because most students enrolled can readily travel to a central location at one of the university's satellite campuses, but lab intensives can lack flexibility. Kitchen labs are experiments designed to be performed in a student's home

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without significant hazards, and often without sophisticated equipment. Kitchen labs are attractive because they provide a flexible, authentic lab experience with minimal safety hazards. Virtual labs allow students to explore concepts through a computer-based simulation and are useful to visualize molecular-scale or other phenomena that cannot be observed, when resources are not available or experiments are too hazardous to perform an experiment at home. For this course, we chose to do a combination of kitchen and virtual lab exercises because of the opportunity to directly link lab and lecture content on a weekly basis and allow flexibility for students.

Distance Laboratory Kits

Mail-delivered lab kits were developed in partnership with eScience Labs (53). We collaborated with eScience Labs to create completely self-contained laboratories with complete step-by-step instructions (Figure 3). We were able to modify several existing experiments from eScience Lab material, but rewrote a substantial portion of the lab manual to refocus on environmental chemistry and Arctic-related issues. We worked closely with eScience Labs, meeting regularly in a combination of remote and in-person meetings during the six months prior to the first course offering. The result was a set of customized lab kits specifically for our course, several newly developed laboratory activities, and a 167-page laboratory manual.

Completed lab kits were shipped to the instructors in Fairbanks so a few remaining supplies could be added prior to shipment to distance students. Added materials included: loaned instructional tablets pre-loaded with a complete lab manual and all applications needed to successfully complete the course, printed packets with copies of the lab manual pages for students to write on, and acid-washed sampling containers used in the research project, and pre-postage-paid thermosafe containers and ice packs for shipping aliquots of research project samples back to UAF during the term.

During the first offering of the course, the instructors held regular office hours both in person for face-to-face students and online through LMS to answer any questions that students might have regarding performing lab experiments. However, there were very few procedural questions, a testament to the excellent lab kit we produced. During the first course offering, the instructional team also met weekly to create videos demonstrating how to perform each laboratory experiment. In future offerings, these videos will be pre-loaded on the lab kit tablets and hosted online to offer maximum support for students while minimizing the required bandwidth.

Several virtual labs were used when the content was either not available or too hazardous to be delivered by air mail. For example, a virtual lab exploring aquatic macroinvertebrates was used instead of a real pond dip because by the 10th week of the semester most surface water in Alaska is frozen (Table 1). We also endeavored to find virtual labs that would be self-supporting or require minimal bandwidth.

On-campus labs relied on the same laboratory manual and experiments as distance students received in mailed the lab kits. This provides an educationally equivalent opportunity for all students enrolled in the course. On-campus labs have the advantage of being less expensive

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to run and the lab fees are lower for the on-campus students relative to the distance students because supplies can be purchased in bulk, do not have to be packed into an individual lab kit, and supplies can be used by several courses to minimize costs.

Lab Safety

Laboratory safety, regardless of physical venue is always of the utmost importance. The instructional team worked extensively with eScience Labs, UAF Environmental Health and Safety, and our departmental safety specialist to ensure that we were doing everything possible to promote a culture of safe practices for both our face-to-face and distance students. Lab kits sent to distance students included standard personal protective equipment, including: safety glasses, gloves, apron, and bench paper. For the field sampling component of the research project personal safety was stressed in the lab manual and in class several times prior to the activity. To manage risk, the instructional team required that each student select a site a week prior to sampling and submit it for approval, which was then considered in conjunction with safety specialists. Life jackets were required (although not provided) when working in and around water. ***It is imperative to work with university safety experts when designing specific protocols for sampling and all aspects therein.***

Peer-Mentored Research Projects

One of our motivations in developing the course was to empower rural students to contribute to meaningful research within their home communities. Alaska has a paucity of data on surface water and drinking water quality in many areas (54). Thus, we could contribute to the state of knowledge in a meaningful way by engaging students in measuring water quality across the state. Because most surface waters are frozen September to April, this course had to be run in the fall semester with sampling occurring as early as possible to be sure that students had liquid-phase natural surface waters to sample and minimize ice-related risks. Students began preparing in week 2 of the semester by identifying a sampling site and submitting it for instructor approval (Table 1). In week 3, students perform a practice analysis with all the equipment used in the field on tap and distilled water, so that students will feel comfortable with the tablets and bluetooth pH, temperature, and redox probes (ORP), as well as the test strips provided. Instructor videos help students select good sampling sites, use proper sampling techniques, and calibrate and use their bluetooth probes properly (55).

In week 4, rural students collect water samples, filter and split their 1 L sample into four 250-ml splits, reserving one for themselves and prepare the remaining three splits for shipment to UAF in coolers provided. On their split they analyze some of the water quality parameters (pH, temperature, ORP). Meanwhile on-campus students prepare for arrival of mailed samples and prepare materials needed for the more sophisticated analyses performed at UAF, including: flame atomic absorption (FAA) to measure cations, ion chromatography (IC) to measure anions, and characterization of dissolved organic matter (DOM) by UV-Visible spectroscopy and fluorescence.

In week 5, all students analyze water quality indicators with on-campus team members duplicating rural student results. Measured parameters include: pH, chloride, alkalinity,

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hardness, phosphate, ammonia, and total iron. Some of these parameters may be altered by the time delay between sampling and measurement which was discussed, but was coordinated in this way for time distribution between labs. On-campus students also make UV-Vis measurements and prepare samples for the more advanced instrumentation, which faculty demonstrate for all students.

In this project, research team members develop different, but equivalently valuable, expertise with the rural students becoming site experts and the on-campus student becoming more knowledgeable about the advanced instrumentation used to analyze waters. While the on-campus students get to experience the site through videos and observations collected by the rural student, they will never have the same understanding as the student embedded in the community where it was collected. Similarly, while videos and explanations of sample preparation are available to rural students, it is not the same as physically preparing samples for the other analysis techniques. However, both experiences are essential to successful completion of the research project. The distance student becomes the site expert, and the on-campus students then also perform Hach test strip kits just like the distance students, but then work together to assess the overall health of the water body.

For the rest of the semester, especially week 13 lab (Table 1), students work in their teams to research more about the water body they sampled and interpret their water quality data. They consider what the water is used for and how human activity might affect the water quality upstream and downstream. Teams examine their measured water quality parameters versus the Alaska State Water Quality Standards to see if they are within legal limits and evaluate the overall health of the water. Students chat by video on the tablets, and then jointly work to develop a presentation about the water quality of that site.

Results

First Offering Successes

The technical aspects of the distance delivery of the course worked very smoothly. There were very few questions relating to performing the lab, despite all students being distance students. Distance delivery of lectures via the LMS was quite smooth and in the rare cases that students were not able to attend class synchronously they could still watch the lecture videos. Both instructors attended and participated in all lectures during the term, which brought diverse perspectives and energy to the presentation of material, and guest lecturers provided additional expertise in specific topics and brought new perspectives into the classroom. One of the most successful parts of the course was the weekly asynchronous discussions, where students interacted above and beyond the requirements by continuing to discuss in a thoughtful way with each other. The self-perpetuating nature of student interactions and depth of student contributions was one of the main successes and joys of the course for the instructional team.

First Offering Challenges

The first offering of this course did not conform exactly to the model we proposed above. The course attracted only three students, all juniors or seniors, and all enrolled in the

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distance course. Students all lived in locations connected to the road system served by the USPS and did not have problems with bandwidth. This was largely attributed to the course first being offered as a trial course that did not fulfill a graduation requirement. However, the course has since gained core designation, which will hopefully help in recruiting our target demographic in the future. We would also like to build relationships with rural campuses to help with future recruitment.

Assessment of Student Attitudes

Formative and summative evaluation of the course was built in from the beginning using an external evaluator who performed pre- and post-assessment of student attitudes and learning, which were anonymized and withheld from the instructional team until after grades were assigned. With the small class size, it is impossible to generate statistically relevant results. However, both of the two students who participated in both the pre and post surveys reported increased likelihood in response to the question, “How likely is it that your eventual career will directly pertain to the environmental field?” Students also reported a strong integration between lab and lecture.

Below are representative student quotes received in the semester-end evaluations:

> “Chem 194 has been a rewarding experience that provided important information on problems in the local environments, as well as larger problems we are facing worldwide. The combination of interesting lectures with practical labs has made the class engaging and fun.”
>
> “I’m really glad I took Chem 194, as it provided me with a wealth of information on environmental problems, and potential solutions to help evaluate and preserve the quality of different ecosystems.”
>
> “The labs were straight forward, and the action of sampling from a field site was a very enriching experience that really tied the class to local issues.”
>
> “Introduction into Environmental Chemistry in the Arctic really peaked my interest and introduced me to many concepts that I had not encountered before.”
>
> “The water project was very unique, and helpful to seeing the connections of water parameters and the topics of many lectures, and how they connect to the environment.”
>
> “I liked the amount of communication with the other class members throughout the semester. I liked having to read and respond to discussion board posts, but not being required to communicate any more often or seriously than that. I was glad I could work independently on the labs and weren’t required to collaborate with others for those.”
>
> “I liked the amount of communication from the instructors to the class about assignments, exams, problems, etc.”
>
> “I’m not sure that the lab was super useful to me. I definitely felt as if it was intended for people that had not worked at all in science before. I liked the overall course content, but the lab felt very simplistic.”

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The tone of most of these comments suggest that, although there are some things the instructional team can improve upon, students valued the course's Arctic focus and it would be appropriate for our target demographic.

Future Work

This course was fully developed in summer and first offered in Fall 2015 as a trial course and has since been approved for a core designation, which also involved moving from a 3-credit to a 4-credit course. This corresponds to an extra hour of lecture per week from the 2015 offering, which will be used to incorporate more active learning strategies, facilitate more in-class discussion, and increase collaboration between on-campus and distance students. It is important for faculty to not just deliverer content and facilitate discussion during synchronous lecture, but also to actively engage with students in all facets of the course, including discussion forums, laboratory activities, etc. Additional data from future offerings will allow for long-term data collection on enrollments, recruitment, and STEM retention.

Unfortunately, subsequent offerings of the course have not yet occurred due to other unrelated constraints. Future offerings will also grow the water quality data sets generated by students within the course. Specifically, we are looking to collect data on basic water quality across the state, a property that is lacking (54) and to present this accumulated data in an online venue for public access.

The next phase of this project will involve developing an interactive map to display student-collected data from the class in a publically available venue (Figure 4). In this way, students can contribute to publically available data on Alaska's surface water. This could eventually serve as a resource for policy makers and scientists in identifying surface water quality concerns and faciliate resource managment decision making.

Potential extensions for the course could include community engagement activities to discuss water quality and/or environmental issues, and to contribute to our knowledge of natural Arctic waters. Partnerships with satellite campuses may also bring mutual benefits of increased enrollments and additional pathways for students to pursue their educational dreams.

Conclusions

This course model describes translatable models for the implementation of an integrated face-to-face and distance laboratory, and a course-based peer-mentored research component. The contextually driven laboratory and research activities may especially serve rural/nontraditional students by identifying issues relevant to their local community and environment. Part of this course's success is improving students' self-identity within science and capitalizing on issues students care about as a mechanism to increase engagement. Our model is specific to Alaska and the Arctic, but the course content can be tailored through case studies, peer-mentored research projects, and exploration of location-relevant environmental issues to other ecosystems. We welcome interest in translating this course model to other ecosystems through collaborative projects.

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Acknowledgments

The authors wish to gratefully acknowledge Chris Iceman, Annie Chartrand, and the Department of Chemistry and Biochemistry for their participation and support of the class. Also, the invaluable contributions of several UAF Biomedical Learning and Student Training (BLaST) Learning, Research, and Training Technicians (LRTTs): Lori Gildehaus, Johanna Green, and Theresa Vertigan for their guest lectures and contributions to the lab. The UAF eLearning staff, especially Madara Mason and Christin Bouffard for their support in course development through the UAF Chancellor's Innovation in Technology and eLearning (CITE) Fellows Program. Our collaborators at eScience Labs, especially Scott Higgins, Ellen Thompson, and Valarie Houghton for taking on this course as a labor of love. Our external evaluator, Lori Sowa, nd the UAF Alaska Summer Research Academy (ASRA) program for supporting the translation of this work to middle and high school audiences. Support for this project was provided by the UAF Office of Undergraduate Research and Scholarly Activities through a 2015 Mentor Award, and the UAF BLaST program through a Curriculum Development Project. Research reported in this publication was supported by the National Institute Of General Medical Sciences of the National Institutes of Health under Award Numbers UL1GM118991, TL4GM118992, or RL5GM118990. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

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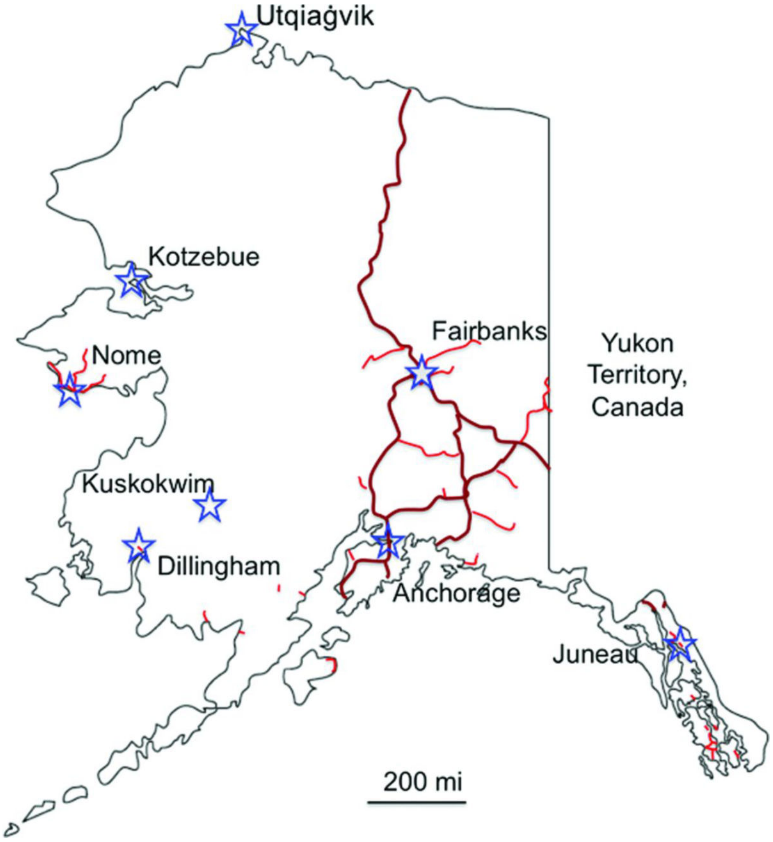

Figure 1.

This course is offered in both distance and on-campus modalities to allow students in rural communities across Alaska to participate and build relationships with students on-campus. Alaska has unique challenges, including a very limited road system.

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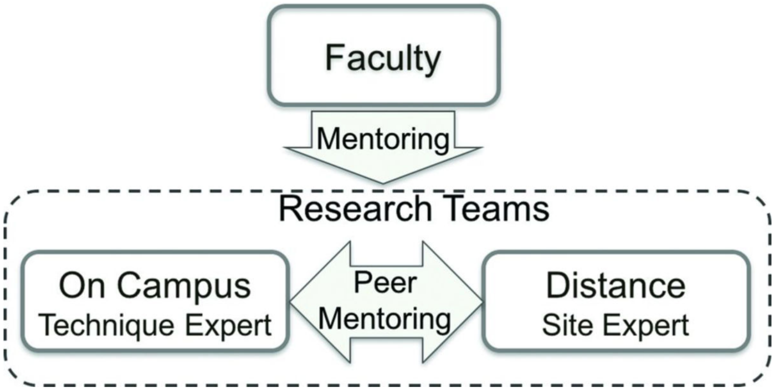

Figure 2.

Theoretical framework for faculty-guided research projects and mentoring of research teams made up of on-campus and distance students.

Figure 3.

Lab manual and lab kit developed for the course through a collaboration with eScience Labs.

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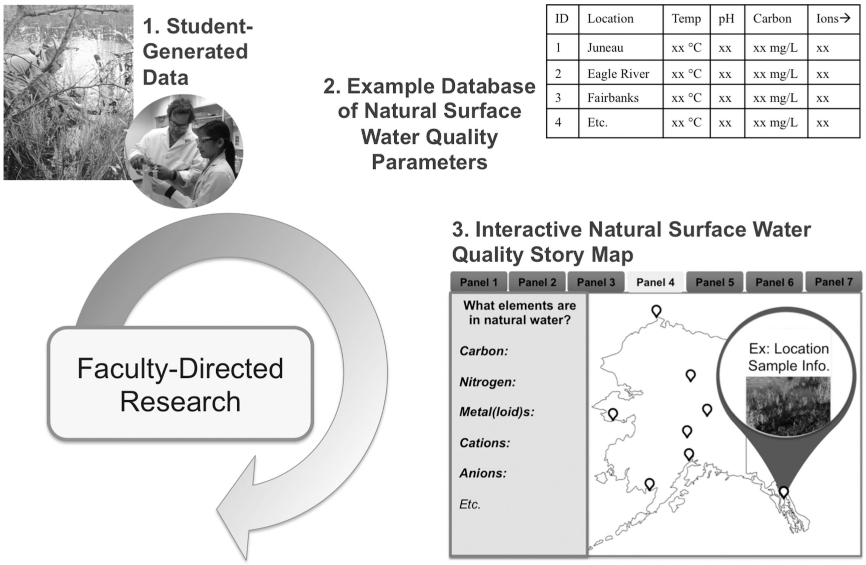

ID	Location	Temp	pH	Carbon	Ions→
1	Juneau	xx °C	xx	xx mg/L	xx
2	Eagle River	xx °C	xx	xx mg/L	xx
3	Fairbanks	xx °C	xx	xx mg/L	xx
4	Etc.	xx °C	xx	xx mg/L	xx

Figure 4.

Collection of student-generated data in an interactive map describing status of surface water quality in the state of Alaska.

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Table 1.

Tentative Course Schedule. Lecture topics, case studies and laboratory experiments are tightly coupled to facilitate student learning.

Wk.	**Topic**	**Case Study**	**Laboratory**
0	Course Introduction		
1	*Labor Day*Intro. to Env. Chem.	The Obligation to Endure	1: Safety and Scientific Method
2	Air Quality	Bear Trouble	2: Air Quality Models and Intro. to pH
3	Introduction to Water Quality	Regulating Triclosan	3: Water Quality and Contamination
4	Water Quality and Treatment	PCB Transport in the Arctic	4: Sampling Surface Water
5	Water Quality of Groundwater	Sulfolane	5: Surface Water Analysis
6	Marine Water Quality	Ocean Acidification	6: Marine Water and Ocean Acidification
7	Contaminant Transformations **EXAM1**	none	7: Contaminant Partitioning
8	Weathering and Soil Formation	Permanent Permafrost	9: Weathering and Soil Formation
9	Metals and Inorganic Contaminants	Pebble Mine	10: Soil Quality and Contamination
10	Environmental Microbiology I	Coliforms in Antarctica	8: Microbial World
11	Environmental Microbiology II	Biodegradation of Oil	11: Biodiversity and Biomagnification
12	Ecological Interactions *Thanksgiving*	Bioaccumulation in the Arctic	No lab
13	Forrest Fires and Ecological Succession	Glacier Bay Succession	Group work on presentations
14	Climate Change in the Arctic	Climate Change Data	14: Energy Sources and Climate Change
15	**EXAM2** 3:15–5:15 pm Final Exam- Student Presentations		