2015

Integrating geoscience into undergraduate education about environment, society, and sustainability using place-based learning: Three examples

David Gosselin
University of Nebraska-Lincoln, dgosselin2@unl.edu

Steven Burian
University of Utah, burian@eng.utah.edu

Tim Lutz
West Chester University, tlutz@wcupa.edu

Julie Maxson
Metropolitan State University, julie.maxson@metrostate.edu

Published in Journal of *Environmental Studies and Sciences* (2015), 10 pp.; doi: 10.1007/s13412-015-0238-8

Published online April 10, 2015.

Integrating geoscience into undergraduate education about environment, society, and sustainability using place-based learning: Three examples

David Gosselin
University of Nebraska-Lincoln, 150 Hardin Hall, 3310 Holdrege, Lincoln, NE 68583-0941, USA
dgosselin2@unl.edu

Steven Burian
Department of Civil & Environmental Engineering, University of Utah, 110 Central Campus Drive, Suite 2000, Salt Lake City, UT 84112-0561, USA
burian@eng.utah.edu

Tim Lutz
West Chester University, Merion 231, 700 South High St, West Chester, PA 19383, USA
tlutz@wcupa.edu

Julie Maxson
Metropolitan State University, 700 East Seventh Street, Saint Paul, MN 55106, USA
julie.maxson@metrostate.edu

Abstract
From water to energy, and from climate change to natural hazards, the geosciences (marine, Earth, and atmospheric science) have an important role to play in addressing a wide range of societal issues, with particular relevance to how humans can live sustainably on Earth. Although arguably important to developing solutions for many societal issues, more often than not, students have limited exposure to the geosciences in high school or college. To address this geoscience literacy problem, the Interdisciplinary Teaching of Geoscience for a Sustainable Future (InTeGrate) Talent Expansion Center has engaged members of the geoscience community and their colleagues in allied disciplines to implement and support strategies to teach geoscience in the context of societal issues and vice versa. Place-based learning is a particularly useful educational practice in helping link geoscience concepts to societal issues and other disciplines. The three examples from three distinctly different institutions of higher education—University of Utah, Metropolitan State University, and West Chester University—demonstrate the use of place-based educational strategies to connect the geosciences to societal challenges. Each of these courses uses variations of place-based pedagogy to provide students from a variety of disciplines the opportunity to learn about geoscience concepts in the context of environmental challenges in their own area. Each example describes the course in the context of its institutional setting, student audience, type of course, and learning outcomes; the geoscience-related societal challenges addressed, a description of pedagogical strategies, basic assessment information, and reflections on lessons learned and recommendations. These three examples illustrate that local places—on-campus, the surrounding community, and regional landscapes—provide a plethora of opportunities for students to apply their classroom knowledge to real-world issues. The extent to which an instructor will take advantage of the place-based opportunities is only limited by the imagination of the instructor(s) and the extent to which they want to use these pedagogies to achieve their learning objectives. Teaching geoscience in the context of societal issues using place-based educational practices illuminate the process of geoscience and build interdisciplinary problem-solving skills that connect geoscience to economic, societal, and policy issues related to a range of issues. Students think critically, ask critical questions, reflect and act on viable alternatives, and acquire knowledge, skills, and training so they can make a real difference in the world.

Keywords: Place-based learning, Geoscience literacy, Societal issues, Sustainability, Higher education, Curriculum change, Undergraduate programs

Introduction

As a society, we face many issues related to natural resources (food, water quantity, mineral/aggregate resources, traditional and alternative energy sources), environmental stability (environmental degradation, climate, environmental justice), and health and safety (natural hazards, water and air quality) as well as questions of sustainability and resilience of Earth's life support systems. Zoback (2001) identified six grand challenges society will face in the upcoming decades for which process level understanding of Earth and environmental systems will be required. These challenges include (1) recognizing the signal within the natural variability; (2) defining mass flux and energy balance in natural systems; (3) identifying feedback between natural and perturbed systems; (4) determining proxies for biodiversity and ecosystem health; (5) quantifying consequences, impacts, and effects; and (6) effectively communicating uncertainty and relative risk. From water to energy, and from climate change to natural hazards and the grand challenges, the geosciences (marine, Earth, and atmospheric sciences) explain the workings of the Earth system, provide the basis for developing best practices for human interactions with Earth systems, and therefore should be firmly integrated into educational pathways (Bralower et al. 2008).

Unfortunately, the current educational pathways in the USA limit exposure for most students to the geosciences to middle school. More often than not, students do not take a geoscience course in high school. A relatively small fraction of all students elect to take a geoscience course during college. The limited exposure to the geosciences minimizes the extent to which people can use geoscientific concepts, ways-of-thinking, and principles to make informed personal and societal decisions about the many Earth, environmental, and natural resources issues society faces currently and in the future. To address this geoscience literacy challenge, the Interdisciplinary Teaching of Geoscience for a Sustainable Future (InTeGrate) Talent Expansion Center has engaged members of the geoscience community and their colleagues in allied disciplines to implement and support strategies to teach geoscience in the context of societal issues and vice versa (Gosselin et al. 2013). InTeGrate supports educational practices that (1) develop geoscience literacy in a broad array of students, (2) illuminate the process of science, and (3) build interdisciplinary problem-solving skills that connect geoscience with economic, societal, and policy issues throughout the curriculum.

One particular educational practice, place-based learning, appears to be particularly useful in helping link geoscience concepts and societal issues. Place-based learning is designed to use the spatial or physical localities that the students experience and to which they are connected (Semken 2012). Place-based instruction tends to motivate students through social, humanistic, and scientific engagement with their surroundings, which lead to the promotion of sustainability of local environments and communities (Gruenewald and Smith 2008). Place-based teaching is cross-disciplinary and intercultural, informed, and contextualized by the natural, cultural, and socioeconomic attributes of the places that are studied (Semken 2012). Sense of place influences the ways people observe and interpret nature and create an important context for learning. Smith and Sobel (2010) indicate that student's motivation and critical thinking are enhanced and that there is more active participation by students in community-based or regional problem solving that leads to improved performance by students. Although placed-based learning is useful, it is important to have examples from different educational and institutional settings that illustrate how it can be used to integrate geoscience with other areas of the undergraduate curriculum.

The purpose of this paper is to demonstrate the use of place-based educational strategies to connect the geosciences to societal challenges at three institutions of higher education— University of Utah, Metropolitan State University, and West Chester University. Each of these examples represents a different type of institution and uses different approaches to provide students from a variety of disciplines the opportunity to learn about geoscience concepts in the context of environmental challenges in their own area. These approaches can be modified to fit other applications related to the reader. For each example, five attributes of the course(s) will be described:

1. Institutional context. Defines the scope of the course including institutional setting (institution type, student population, department/program location), student audience (course numbers, who takes the course, etc.), type of course (general education, major, level), and learning outcomes.
2. Grand challenges. Geoscience-related grand challenges that are addressed in the course.
3. Pedagogical overview. Specific examples of place-based pedagogies integrated with other strategies to help students address interdisciplinary challenges, provide opportunities to experience the nature and methods of geoscience and the use of geoscience data, and/or improve student's abilities to think about systems.
4. Assessment information. Depending on the context of the course summative and formative assessment data have been collected that relates to the effectiveness of the course in the context of the learning objectives for the course at the given institution.
5. Lessons learned and recommendations. By presenting the nuts and bolts of these educational approaches at three institutions, others can move forward with their plans to integrate geoscience into addressing societal issues.

Example 1. University of Utah, Salt Lake City, Utah

Institutional context

The University of Utah is the flagship institution of higher learning in Utah, serving approximately 30,000 students from across the USA and the world. The institution is classified as very high research activity according to the Carnegie Foundation. Sustainability has been a recent emphasis, with its introduction as a core value in 2012. The University of Utah has recently directed considerable attention and resources toward advancing sustainability education and scholarship, in addition to an aggressive program to be carbon neutral by 2050. Key recent accomplishments include the creation of the Global Change and Sustainability Center (http://environment.utah.edu), the introduction of interdisciplinary sustainability certificates at the undergraduate and graduate levels (http://ugs.utah.edu/sustainability-certificate/index.php), and the formation of a pan-campus Sustainability Office to coordinate and promote all activities.

Recently, challenges related to water resources have intensified and diversified in Utah because of growing metropolitan populations, aging infrastructure, changing climate, and improved awareness of environmental impacts. In addition, public policy related to water issues has become much more nuanced and complex. In response to this intensification of water issues, the inability of a single discipline to address the complex issues, and the emphasis on sustainability at the University of Utah, a new course was developed. The course, called Hydrotopia (Burian and Barbanell 2010; Burian et al. 2011), combines concepts from water resources engineering, geosciences (specifically Earth and atmosphere), philosophy, law, planning, economics, political science, and social sciences to address the challenges of water resources planning and management. This course exposes a disciplinary-diverse set of students to geosciences. Hydrotopia is a team-taught course by professors in civil engineering (Burian) and philosophy (Ed Barbanell). It takes a systems perspective and brings students together to explore "water" and "place" in the context of water management.

Historically, civil engineers have planned and designed water infrastructure to prevent floods, supply water, collect stormwater and wastewater, generate hydropower, and manage waterways. The goal of this course is to develop the next generation of professionals responsible for planning, designing, managing, and operating water resources systems and facilitating the interaction of those systems with society. The learning objectives for the course are provided in Table 1. The course is offered through the Department of Civil and Environmental Engineering and the Department of Philosophy with cross listing in other departments. It is designed as an elective for upper level undergraduate and entry level graduate students. As a result, the course attracts a diverse student population, with enrollment being limited to 30 students, half from Science, Technology, Engineering, and Math (STEM) and half from non-STEM disciplines.

Table 1. Learning objectives for Hydrotopia

1. Explain water projects to non-technical people
2. Navigate water rights administration process
3. Describe multidisciplinary elements of water projects
4. Analyze water management decisions using modeling tools
5. Assess implications of technical and non-technical water project solutions and decisions in a societal context
6. Effectively communicate with others to develop, judge, and recommend multi-objective solutions to water resources challenges

Geoscience-related grand challenges facing society

The course addresses the grand societal challenges of providing clean water and protecting the natural water environment. Considering the grand challenges presented by Zoback (2001), the course addresses three (of the six) challenges:

- Identifying feedback between natural and perturbed systems
- Quantifying consequences, impacts, and effects
- Effectively communicating uncertainty and relative risk

Within the context of the course assignments, discussions, and guest speakers, students are exposed to philosophical and legal concepts, hydrologic science principles, climate and risk analysis concepts, metropolitan planning methods, water resources engineering design and management techniques, water management modeling and analysis tools, and more. Specific topics vary each time the course is offered; however, the typical core topics include water scarcity, water law, hydrologic cycle, water planning, water infrastructure, water management modeling, water-energy nexus, technological solutions, environmental impacts, aging water infrastructure, climate impacts and risk, city planning, and restoration.

Overview and examples of pedagogy

The pedagogical approaches involve traditional lectures, discussions, active learning activities, a problem-based learning module, and project-based learning experience. These instructional strategies are employed using the context of water and place. As examples, the course has had past themes of Colorado River Basin Water Management and Sustainable Water Management of the Salt Lake City Metropolitan Area. Each activity in the class is linked to these place-based themes and invites students to explore water sustainability opportunities as they learn fundamental knowledge and applied skills related to water management. The place-based linkage is strengthened by incorporating field trips and guest speakers programmed by the instructors. In addition, the instructor team identifies local water events/activities (e.g., conferences, films, and service) that can reinforce class concepts and encourages student participation and engagement.

The pedagogical approach to stimulate discussions is to use position papers as the primary writing assignment. Students are assigned positions to force them to write from a range of perspectives on local water projects/issues (e.g., new dam, dam removal, transboundary diversion, and water reuse). This approach forces students to take positions in their papers (and ensuing class discussions) with which they may not agree personally or professionally. Students that have personal connections to the places that are the subjects of the debates are especially challenged. In addition, the assignments force students to focus on facts and logical reasoning. The assignments require students to define uncertainty of the information/data they use to support their argument, and to consider risks associated with their position. Past student feedback suggests that these position paper assignments force the students to appreciate the opinions of others, and the importance of making fact-based, data-driven arguments (Burian and Barbanell 2010). Writing and speaking skills are also stressed in these assignments and discussions.

A second key pedagogical approach employed is problem-based learning (PBL). Students are given the problem of achieving water neutrality for the University of Utah to guide the activities in class and out of class for a 2-week learning module. Students are divided into teams to work through a series of task requirements: (1) define water neutrality; (2) accumulate water, climate, and other necessary data resources to analyze the time varying water budget; (3) create a system model using a spreadsheet, water management model, or other tool; (4) judge the university's water neutrality; and (5) devise solutions to remedy. An important aspect of this PBL module is the use of data because students get exposed to instructor-selected datasets and are guided through a series of visualization, analysis, and assessment activities that engage them directly with geoscience data (e.g., precipitation and hydrologic) and geoscience thinking. In addition, students are encouraged and aided to think of the broader system that influences the coupled natural–human-built water system of their local environment, the University of Utah. Student understanding of the broader system and how water fits is aided by visits from practicing engineers, geoscientists, and administration officials and guided walkabouts during the module.

The third pedagogical technique used in Hydrotopia that addresses the goal of exposing students to geosciences and other disciplinary perspectives is a team-based learning experience. A project is assigned to teams of students selected by the instructors to have a diversity of disciplines. The teams are specifically designed to try to include one geoscience, one engineering, one humanities, and one other discipline. The project topics are selected by the students, but they must include tasks/activities that use the team members' respective knowledge and skills. In this way, geoscience (and other) disciplinary knowledge and skills are distributed using a peer-to-peer pathway.

Assessment

Burian and Barbanell (2010) conducted an assessment of student learning related to course goals and student preferences related to course design and pedagogy. The accomplishment of learning goals was assessed through assignments, class discussions, and the team project. Embedded indicators were incorporated into assignments to measure student performance. Results indicated that 100% of students achieved the expected levels in Bloom's taxonomy for learning goals 2, 4, and 5 (see Table 1). Learning objectives 3 and 6 were in need of improvement with less than 100% of the students successfully responding to the embedded indicator.

Burian et al. (2011) further analyzed the challenges associated with the interdisciplinary course as they related to communication barriers and how the course was re-designed to overcome them. The strategies tested and assessed were as follows: providing learning objectives, keeping a journal, use of outside events (conferences, speakers, movies, and activities), instructor role-playing of disciplinary perspective, case studies, problem-based learning, and project-based learning. Students were surveyed, and the strategies identified by the student assessment as most effective for helping them bridge the disciplines were outside events, multidiscipline instructors, problem-based learning, and project-based learning.

Lessons learned and recommendations

The course is massively multidisciplinary, which creates numerous challenges to overcome to achieve the learning goals. It was apparent after the first course offering that students were lacking in achievement of describing multidisciplinary elements of water projects (learning objective 3) as noted by poor description of the relationship of their projects to local environmental and human systems in their project reports. This led the instructors to incorporate greater systems thinking and fundamental knowledge of Earth sciences (e.g., hydrology) into the next offering of the course in the form of lectures and in-class exercises. Interestingly, the incorporation of these exercises and lectures was found by Burian et al. (2011) to contribute to enhancing communication across disciplines. Students noted that the improved understanding of the broader system interconnections to their place-based water issue and the establishment of a common base of fundamental knowledge in hydrology improved their ability to interact across disciplinary boundaries. This aided the achievement of learning objective 6.

Overall, the Hydrotopia course has been a great success. Students enjoy the experience, gain respect for disciplines, learn to use geosciences knowledge and datasets and to represent uncertainty, and in general comprehend the value of geosciences in water resources management. Still, more can be done. The value of the use of geosciences data is anecdotal; therefore, a more formal assessment is needed. One area that can be enhanced is the required use of geosciences data in the team project. The course would also benefit from bringing practicing geoscientists in as guest lecturers. Furthermore, the team project can include greater interaction with practicing geoscience professionals in addition to the usual engineering client. All of these elements will be weighed and potentially incorporated into future offerings.

Example 2.West Chester University, West Chester, Pennsylvania

Institutional context

West Chester University is primarily an undergraduate, regional comprehensive university located in southeastern Pennsylvania. It has approximately 16,000 degree seeking students. West Chester University recently completed a Climate Action Plan, which includes a commitment to make sustainability and climate change part of the curriculum and educational experience of all West Chester University (WCU) students. Humans and the Environment (ESS102) fulfills an interdisciplinary requirement within the general education program. The course studies the ability of humans to survive and maintain their life quality, considering the limited resources and recycling capacity of planet Earth. The specific learning objectives are provided in Table 2 and focus on thinking skills—critical, analytical, and systems thinking and informed decision making.

Over the years, the instructor (Lutz) has oriented the course toward the problems of living sustainably. It is taught in sections of 32 students who typically range from freshmen to seniors and are enrolled in one of five colleges: arts and sciences, visual and performing arts, business and public affairs, health sciences, and education.

Geoscience-related grand challenges facing society

At its essence, the course recognizes that all of Zoback's (2001) grand challenges are symptomatic of the unsustainable character of the relationships between humans and Earth's systems. As early as 1865, George Perkins Marsh noted that humans were having a deleterious effect on Earth's landscape that far exceeded their numbers (Marsh 1865). As he put it, our capacity to alter Earth exceeds every other organism in "both kind and degree." Despite tremendous advances in our scientific understanding of Earth, Hooke and others (2012) find evidence that we are now in a state of overshoot: Primary Earth systems resources (e.g., agricultural soil, fresh water, and biocapacity) are being consumed or degraded at higher rates than they are being regenerated. The implications are unavoidable: The patterns of economic, scientific, technological, and political thought over at least the last 150 years—our modern worldview—have brought us into overshoot.

Table 2. Learning objectives for Humans and the Environment

Students will be able to:

1. Think critically and analytically about their connections to the systems they are part of, spanning natural, social, and economic systems. (96.5%, n=170)
2. Demonstrate the ability to think across and about disciplinary boundaries to achieve the worldview needed to learn from earth's systems and human systems. (92%, n=170)
3. Make informed decisions and ethical choices by actualizing sustainability as a system dependent on both fact and value. (94.5%, n=170)

To move toward a sustainable path, it is not sufficient to teach students about individual challenges to our environment, no matter how "grand" they may seem. The overarching themes of the course is to provide transformative experiences that challenge the student's existing world view. Moreover, the course seeks to dispel the illusion that human ingenuity is keeping pace with the current use of resources and the damage being inflicted upon planetary support systems by human activity. Students are provided opportunities to develop a vision for how sustainable systems work using the best example, that is, life on Earth. Organisms have been coexisting and co-evolving with Earth's abiotic systems for at least 3.5 billion years, despite catastrophes both endogenic (e.g., oxygen catastrophe) and exogenic (meteoroid impact). What rules did Earth "learn" to provide extraordinary resilience to change, and that we have seemingly forgotten?

Overview and examples of pedagogy

One foundational pedagogy for the course is that of systems thinking, specifically the concept of cybernetics, which is the study of how organization, communication, and control occur in complex systems (Bateson 2002). Bateson argued that any system with the potential to be self-perpetuating possesses a common set of cybernetic characteristics, including some familiar to Earth systems modelers:

1. All components of the system must be connected via flows that transmit information of difference. Changes in one part of the system are communicated to every other part. There is connectivity and responsiveness to difference regardless of the specific "language" of communication—physical, chemical, geological, or biological.

2. System components respond dynamically through feedback in such ways as to maintain the whole system. Each complex system, through its history, develops its own meaning for stability. On Earth, maintenance of conditions suitable for life became, over 3.5 billion years, a defining characteristic of planetary stability.

Throughout the course, cybernetics is used to probe the self-contradictory status of humanity. For example, we accept that Earth systems operate holistically and need to be understood in cybernetic terms, yet we see ourselves as fundamentally separate from nature and operate our human-built systems as though they were independent of their reliance on Earth systems. The course recognizes that scientific disciplines (e.g., chemistry, geoscience, and biology) and subdisciplines (e.g., geochemistry, mineralogy, petrology, stratigraphy, and paleontology) are artificial human constructs, each interesting and informative on its own, but each incapable of providing the essence of the complete Earth system metaphor. In addition, human behavior needs to be considered as a variables in the Earth system metaphor. For example, climate models demonstrate the cybernetic separation of humans from Earth systems. In climate models, all system components, such as the atmosphere, oceans, glaciers, sea ice, soils, and biota, dynamically react to signals from every other component. Human behavior, though, is considered an independent variable: We affect Earth's climate but our behavior cannot be modeled or predicted.

As the course proceeds, a basic question is continually asked, "How can we achieve cybernetic understanding of our place in the world, and what would be different if we could?" These are questions for which there are no ready answers. The course seeks to augment what we learn from natural systems by raising our awareness of their cybernetic as well as their physical character. In the quest for cybernetic understanding, both undergraduates and professors find themselves grappling with the same questions and this motivates modification to teaching and learning.

A second foundational pedagogy is place-based learning. Outdoor experiences are vital to develop an intuitive understanding of cybernetics in real systems. The course utilizes a woodland watershed (WCU's Gordon Natural Area) and various components of the urbanized campus to practice cybernetic thinking. In the outdoor environment, students are encouraged to shed their assumptions that the study of nature is only a matter for science. Furthermore, these campus areas are daily parts of many students' lives, leading to opportunities for continuous reflection on the questions raised by the course throughout the day.

In one 75-min period, the class walks from the upland areas of a small (~23 ha) watershed to a streamside overlook. The objective is to consider a broad question such as, "Why does the valley and its stream look as they do?" As the class walks, students look for the traditional Earth cycles—e.g., the hydrologic cycle, the rock cycle, and the biologic cycle—at work as they combine to shape the landscape. The students come to recognize that no cycle works alone, all are interconnected in space and time. For example, a tree fallen along the valley side that forms a dam across a deer trail on the slope traps colluvium as runoff, and gravity moves weathered rock, soil, leaf litter, and twigs downslope. The forest floor slopes gently downward toward the dam and then drops abruptly across the log, where runoff creates a miniature waterfall that erodes a pool. Elsewhere, similar logs decompose, allowing the accumulated colluvium to erode, again reshaping the slope and redistributing the soil and nutrients from which sapling trees grow. The valley stream reveals a similar recurrent interplay among the cycles as the dynamics of flowing water and sediment, rock outcrop, and the trunks and roots of trees shape its channel. The students find it evident that the watershed is a unified system that essentially reshapes itself continuously. The current path and form of the channel and the valley are the momentary outcomes of the dynamic whole.

In another period, the students study the urbanized landscape of the main campus. The significance of using the human-built environment is that it provides students the opportunity to explore their world view and relationship with nature. Students reflect on the big question, "What are the cybernetics of our built environment?" They examine the buildings and walkways and how they fill the landscape. The elements of Euclidean geometry, straight lines, planes, and arcs of circles, predominate are recognized by the students. The regularity and stasis of the built environment contrast with virtually all natural systems in which the Euclidean geometric components are absent and the constantly curving, shifting paths of a stream or the growing arch of a tree limb are the norm. Interactions of nature with the built environment are examined in detail. For example, runoff flows off the side of a long walkway made of square tiles laid in rows along concrete rectangles. The flowing water erodes a sinuous channel at the contact of the concrete with the plants and soil of the adjacent lawn. This channel constantly adjusts its path and elevation over time. In some places, the walkway is undermined and at others covered by silt, threatening the stability and obscuring the regularity with which it was built. Flattened surfaces of schist and serpentine building stones are weathered into irregularly shaped hollows between the linear mortar joints.

Assessment

West Chester University's general education program has goals that each course translates into measurable outcomes. The objectives in Table 2 show how general goals, such as thinking critically and analytically, are made more specific by relating them to the Earth systems orientation of Humans and the Environment. In the last two semesters, outcomes were evaluated indirectly via anonymous end-of-semester surveys. The percentage of students who "agree" or "strongly agree" that the course enhanced their ability to achieve each objective follows each entry in Table 2 and exceeds 90% for each. In spring 2014, objective 2 was assessed directly by using a rubric to score 83 student essays on a four-point scale. Fifty-two percent scored in the highest two categories and were able to substantially "demonstrate the ability to think across and about disciplinary boundaries" by comparing disciplinary and interdisciplinary approaches, by explaining systems thinking in relation to sustainability, and by giving examples that interrelated human and natural systems. The results indicate that most students are able to benefit from a locally based, systems-oriented approach. We aim to "close the loop" by using our assessment process to increase that percentage.

Lessons learned and recommendations

One of the challenges of juxtaposing the natural and human environment is that it exposes students to the contradictions in the ways human's think. This creates challenges for both students and instructors. On one hand, we claim that we live in a world of interconnection among all systems; on the other, we think that we can avoid the interconnectedness in planning how research is conducted, designing our curricula, and teaching our students. We live on a complex, dynamic planet; however, we build our university environments to embody an ethos of linearity and stasis. Bateson (2002) stated the issue as, "What we believe ourselves to be should be compatible with what we believe of the world around us." If we recognize in nature the potential to live sustainably, we need to expose the incompatibility of our actions as humans with this type of lifestyle. This aspect of the course is captured by its learning objectives (Table 2): It is not "about" particular content but rather how we think about ourselves in relation to the way Earth is.

Students sometimes ask, "How could we possibly learn to think differently about ourselves in relation to Earth systems?" This example can be used: Every student accepts that there is a "right" answer to questions such as, "How far is it from point A to Point B?" In other words, they are used to thinking that the distance between two points is a unique value, and scientists thought this way for hundreds of years, too! However, geoscientists helped discover that a different concept— fractal measure—is needed for distances in nature because the complexity of Earth's systems create nonlinear patterns (e.g., Turcotte 1997). For example, the distance along a meandering stream channel is related to the length of the ruler used to measure it; there is no unique answer but rather a relationship. Educators and education researchers are beginning to embrace complexity theories as the bases for new ways of thinking about what we teach and how we teach (e.g., Davis and Sumara 2006; Doll et al. 2008; Mason 2008). By confronting the contradictions in our worldview and being guided by such theories, we and our students might begin to see things in radically new ways.

Example 3. Metropolitan State University, St. Paul, Minnesota

Institutional context

Metropolitan State University is an urban public university in the Twin Cities (Minneapolis and St. Paul, Minnesota) that primarily serves working adults. It has a student population near 8000. A significant majority of Metropolitan State University students are considered non-traditional; the student body includes first-generation college students, veterans and military students, and students of color (36%),many of whom are recent or second-generation immigrants from Somalia and Laos.

General education goals, defined for all state colleges and universities in Minnesota, require students to take a laboratory science course as well as a course that addresses learning outcomes defined as "People and the Environment" (Table 3). Courses that combine these two general education goals are particularly in high demand: Consequently, the Natural Sciences Department offers three to five such courses or sections each semester. This case focuses on two of these courses, taught by J. Maxson, Environmental Science and Environmental Geology. A key focus of each of these courses is the concept of sustainability, and an emphasis on the identification of environmental problems and how they can be solved. Within the next 2 years, both of these courses will become gateway courses into a new major in Environmental Science.

Table 3. Learning objectives for People and the Environment courses.

Objectives 1–3 are defined within the MNState Colleges and Universities General Education guidelines. Objectives 4 and 5 are specific to the design of the courses described here.

1. Explain the basic structure and function of various natural earth systems, and of human adaptive strategies with respect to those systems
2. Critically evaluate environmental and resource issues in light of understandings about interrelationships, ecosystems, and human institutions
3. Recognize and articulate the global socio-economic, political, cultural, and racial disparities in access to environmental resources and sustainability solutions
4. Relate the course content directly to the student's home communities
5. Articulate a scientific understanding of environmental problems and their solutions, in both empirical and applied science

Geoscience-related grand challenges facing society

Because geoscience and environmental science courses have been taught primarily for general education students at Metropolitan State, rather than as pre-requisites to advanced undergraduate science courses, course content can be varied and tailored to specific learning outcomes.

Each of the "grand challenges" for sustainability defined by Zoback (2001) and advanced by the InTeGrate program can be identified and applied to environmental systems and environmental problem solving in the Upper Midwest. The grand challenges are played out particularly with respect to three broad areas of environmental concern: (1) the methods and environmental consequences of agricultural land use, (2) historic and future mining operations throughout the region, and (3) management of the Mississippi River and Great Lakes watersheds, in terms of water resources, ecosystem conservation, and flood control.

Overview and examples of pedagogy

Based on research linking place-based learning and student engagement (e.g., Semken 2012), the Environmental Science and Environmental Geology have emphasized one or more of the following: local and regional environmental issues; issues that pertain directly to neighborhoods or communities in Saint Paul or Minneapolis, or outlying suburban and rural communities; or significant economic or political concerns in the Upper Midwest. The place-based emphasis is pedagogically strategic in another way: Both the instructor's reflective practice and research on non-traditional learners (e.g., Knowles et al. 2011) establish that adult learners, to a greater degree than traditional-aged students, need to see immediate applicability of their course work.

Beyond establishing immediate relevance in place-based investigations, a pedagogical benefit of focusing on the three broad areas of concern described above (agriculture, mining, and watershed management) is that each of them overlaps with the others. They therefore provide a rich context for the development of a student's understanding of complexity in physical, chemical, and biological systems, and the anthropogenic perturbation of those systems.

Students are introduced to these systems using a variety of pedagogical approaches that include lectures, documentary films, open-ended as well as fixed-outcome laboratory investigations, Google Earth tours, and field laboratories. As a result, most students come to recognize the complexity of interactions among agriculture, extractive industries, and regional surface and groundwater systems. For example, agricultural practice in Minnesota directly impacts water quality in the Mississippi River and the Gulf of Mexico; water quality and water chemistry directly influence the success of invasive species; proposed mining of southern Minnesota's Paleozoic sandstones for use as proppant (also known as frac sand) competes with agricultural use in the region and impacts water quality.

A final aspect of the pedagogic design of the courses is to move students from a scientific understanding of environmental degradation in complex physical-chemical-biological systems to the necessity of problem solving. It is here that students recognize that scientific knowledge is both essential to and insufficient for environmental problem solving. Solutions must be scientifically sound but are overlain by the economic, political, and social justice concerns in environmental decision making.

The emphasis on environmental problem solving culminates in an independent research project and class presentation. The research may involve a small-scale primary scientific investigation, a literature review, or an informational interview with individuals or agencies engaged in environmental problem solving. An evaluation rubric provided to students at the beginning of their project guides them to ground their topic in the connection between natural science, technology, and the human environment; consultations with the instructor help students refine their topic development, types and methods of data acquisition, and sources of information.

One of the great benefits to all participants, students and instructor alike, is that students apply their new knowledge of environmental problems and problem-solving to areas of particular concern to them. Students are encouraged to focus on environmental concerns that directly affect their home communities and neighborhoods, either in the greater Twin Cities or, for international and immigrant students, in their regions or countries of origin (Table 4).

Presentations often expand the course focus to include national and international topics. The specificity as well as the breadth of student projects speaks to student attainments of a key learning goal for the courses: that students will be able to apply their learning about environmental degradation and sustainability solutions to other issues and regions of concern.

Assessment

The efficacy of a place-based approach to course design is made evident in student comments on end-of-course evaluations. Although quantitative data is not currently available, student comments indicate a high degree of student engagement with the course material as a result of the local and community emphasis:

Characteristic responses to the course evaluation question "What was the most valuable aspect of the class for you?" include the following:

- Field trips practice/see what we had learned.
- Local, practical examples and topic discussions.
- Learning about the local environment.

Table 4. Recent examples of student research topics for "People and the Environment" courses at Metropolitan State

1. Groundwater Withdrawal in Suburban St. Paul and Drawdown of White Bear Lake
2. Constructing Residential Rain Gardens: examples from Eagan, MN
3. The Challenges and Successes of LEED Certification of Target Field (the Minnesota Twins Ballpark)
4. Toxic Exposure Risks for Firefighters
5. The Environmental Impacts of Disposable Diapers
6. Impacts of the Minneapolis Waste Incinerator on Local Residents: Urban Inevitability or Environmental Racism?
7. Frac Sand Mining: A Comparison of Policy and Practice inWisconsin and Minnesota
8. Increased Flood Frequency and Magnitude on the Upper Mississippi River: Climate Change or Urbanization?
9. Toxic Mine Drainage from the Baia-Mare Gold Mine, Romania
10. Environmental impacts of petroleum extraction in the Niger Delta
11. Toxic Dumping in the Indian Ocean and Impacts on Somali Coastal Communities
12. Living Down-wind of Chernobyl Nuclear Disaster, Then and Now

- How relevant the material was. It seems like the info in the class is more important than the info from any other class I've taken.
- Lots of tidbits to anchor the material to Minnesota.
- The course explored the ethical questions in relation to our local environment.

Other student responses emphasized changes in behavior or in thinking about the environment:

- [The course] showed me to actually look at what I'm doing in my home or community.
- The Real World knowledge was excellent. I found myself sharing what I learned with family and friends on a regular basis.
- My stand on the environment has changed by a lot. I am more concerned about our environment than I was before and plan to take steps to spread what I've learned to others who could do the same.

Lessons learned and recommendations

Because the majority of Metropolitan State University students are adult residents of the Twin Cities, they are strongly place-based, having roots in the urban area and/or the region. They are also far more aware of local and regional events and issues than are most traditional-age students. This awareness provides a distinct advantage for engaging students in geoscience and environmental content.

Including opportunities for students to establish skills in scientific systems thinking, and then to move beyond scientific content to incorporate economic, political, and socio-cultural ideas and ideals has been a key to student success among diverse, adult learners. This observation is consistent with research by Knowles et al. (2011) indicating that adults are most motivated by, and learn best from, opportunities for practical application of course content.

Summary and conclusions

Examples of interdisciplinary courses from three distinctly different institutions of higher education—University of Utah, Metropolitan State University, and West Chester University— indicate that place-based pedagogy provides students critical opportunities to learn about key geoscience concepts in the context of important environmental challenges in their own area. The assessment data collected, most of which would be considered formative in that it is used to support instruction improvement decisions, is consistent with Gruenewald and Smith (2008) that place-based instruction serves to motivate students through social, humanistic, and scientific engagement with their surroundings. In addition, the albeit limited feedback from students at all three institutions indicates that student's motivation and critical thinking were enhanced by their active engagement with real-world societal problems and environments. Based on work by Smith and Sobel (2010), one would expect that student performance improved as a result. The three examples also are consistent with a community-centered approach advocated in Bransford et al. (2000) that emphasizes that learning is a social endeavor and that connecting students to the outside world gives context to their learning.

It is clear that local places including on-campus, the surrounding community, and regional landscapes provide a plethora of opportunities for students to apply their classroom knowledge to real-world issues. One area in which all students need more opportunities to apply their knowledge is on thinking about complex systems. An emphasis on systems-based thinking was an important attribute of all three place-based courses. It is important to recognize that systems-based thinking was not only important to understanding the natural system, it was important for students from all disciplines in recognizing the connections and feedback between the natural systems, social sciences, and the humanities. As a result, respect for and among all disciplines was a positive outcome among all students involved in the three courses. Connecting to issues and exploring them using a systems approach also provided students the opportunity to recognize that solutions to societal problems are complex and require interdisciplinary solutions. In addition, these three case studies illuminate the process of geoscience and build interdisciplinary problem-solving skills that connect Earth science to economic, societal, and policy issues related to a range of issues. Students are asked to think critically, ask critical questions, reflect and act on viable alternatives, and acquire knowledge, skills, and training to make a real difference in the world.

Place-based learning and teaching is an extremely valuable pedagogy, but it does take time and effort along with ongoing reflection by the instructor to take full advantage. The extent to which an instructor takes advantage of the place-based opportunities is really only limited by the imagination of the instructor(s) as illustrated in the three examples. All three examples illustrate the importance of planning the course with the end in mind and considering the students who will be served by the course. When planning-with-the-end-in-mind, the instructor(s) articulates what they want the students to know and be able to do. A key word in the last sentence is students. In each of the courses described, different student audiences were involved. In the case of the Minnesota State students, they were dominantly adult, non-traditional students and they have different expectations than traditional 18–24- year-old students. A key concept here is that it is important to know your audience. When you articulate what the students should know and be able to do, it needs to be done in the context of your expectations, your institutions' expectations (e.g., general education requirements), and your student audience's expectations. These expectations are your learning objectives for the course. In the case of these three examples, each course had a different set of learning objectives (Tables 1, 2, and 3). In addition, they all had had different levels to which geoscience concepts were to be involved. After setting the learning objectives, the next thing that needs to be done in the context of place-based pedagogy, in particular, is "your place" going to facilitate the learning of your objectives. You will also need to consider how you will use other student-centered pedagogies such as problem-based learning, systems-thinking, and project-based learning to use "your place."

Acknowledgments — This work is supported by a National Science Foundation (NSF) collaboration between the Directorates for Education and Human Resources (EHR) and Geosciences (GEO) under grant DUE - 1125331. Any opinions, findings, conclusions, or recommendations expressed in this paper are those of the authors and do not necessarily reflect the views of NSF. The authors would like to thank Cathy Manduca, Jean MacGregor, and Rick Oches for hosting the workshop that brought the authors together.

References

Bateson G (2002) *Mind and nature: a necessary unity.* Hampton Press, Cresskill

Bralower TJ, Feiss PG, Manduca CA (2008) Preparing a new generation of citizens and scientists to face earth's future. *Lib Educ* (Spring Issue):20–23

Bransford JD, Brown AL, Cocking RR (eds) (2000) *How people learn: Brain, mind, experience, and school.* National Academy of Sciences, Washington, DC, 374 p

Burian SJ and Barbanell EM (2010) "Hydrotopia: integrating civil engineering and humanities to teach water resources engineering and management." *American Society for Engineering Education (ASEE) Annual Conference Proceedings, 20-23 June, 2010*, Louisville, KY

Burian SJ, Barbanell EM, Blevins M (2011) "Avoiding another Tower of Babel: Bridging communication barriers among students and instructors from civil engineering, humanities, and other disciplines in a multidisciplinary course." *American Society for Engineering Education (ASEE) Annual Conference Proceedings, 26-29 June, 2011,* Vancouver, BC, Canada

Davis B, Sumara D (2006) *Complexity and education: Inquiries into learning, teaching, and research.* Routledge, New York

Doll WC, Fleener MJ, Trueit D, St. Julien J (eds) (2008) *Chaos, complexity, curriculum, and culture: A conversation.* Peter Lang, New York

Gosselin DC, Manduca C, Bralower T, Mogk D (2013) Transforming the teaching of geoscience and sustainability. *Eos* 94(25):221–222

Gruenewald DA, Smith GA (eds) (2008) *Place-based education in the global age: Local diversity.* Lawrence Erlbaum, New York

Hooke RL, Martin-Duque JF, Pedraza J (2012) Land Transformation by humans: A review. *GSA Today* 22:4–10

Knowles MS, Holton EF III, Swanson RA (2011) *The adult learner; The definitive classic in adult education and human resource development,* 7th edn. Elsevier, New York

Marsh GP (1865) *Man and nature; or, physical geography as modified by human action.* Charles Scribner, NY

Mason M (2008) *Complexity theory and the philosophy of education.* Wiley-Blackwell, Oxford

Semken S (2012) Place-based teaching and learning. *Encyclopedia of Learning.* Springer Science+Business Media. doi:10.1007/978-1– 4419-1428-6_1739

Smith GA, Sobel D (2010) *Place- and community-based education in schools.* Routledge, New York

Turcotte DL (1997) *Fractals and chaos in geology and geophysics,* 2nd edn. Cambridge University Press, New York

Zoback ML (2001) Grand challenges in earth and environmental sciences: Science, stewardship, and service for the twenty-first century. *GSA Today* 41–47