InTeGrate Workshop: Systems, Society, Sustainability and the Geosciences
July 24 - 26, 2012 - Carleton College, Northfield, MN
Participant Essays

Nelson Altamirano, School of Business and Management, National University

Economics, Sustainability and Interactive Teaching Approach

My discipline is economics and of course I teach microeconomics or macroeconomics most of the time but working at the School of Business and Management has forced me to think in interdisciplinary and practical terms. My students are not economists and don't want to be economists; most of them are adults with rich life and working experience that always want to relate economics to their own backgrounds. They have strong beliefs or pre-conceptions that are always contrasting with the new information from the classroom and frequently contrasting models with reality. Given that economic issues in reality depend on social, political and natural factors, I cannot limit my teaching to pure economics models and usually find myself in the crossing borders between economics, political science, and sociology. Now I would like to find that border with geosciences when teaching environmental economics or sustainability.

Learning environmental economics and sustainability concepts requires the understanding of how the earth system works, and for social sciences it is crucial to identify how social and economic activity depends on that system, as well as, affect or alter that system in the short run and long run. While the focus of my courses are in the social and economic content of that process, a clear and deep understanding of geosciences fundamentals would be a must. Key topics we talk in my courses and would enormously benefit from geosciences components are: climate change, temperature changes, ocean levels, air pollution and flow of winds, water contamination, deforestation, deep water drilling, horizontal drilling and cracking in shale gas, oil spills, coal mining versus natural gas exploitation and refining, biological diversity and loss of diversity, overexploitation of fisheries and renewable resources, termination of non-renewable resources, sustainable exploitation of non-renewable resources, green measures of economic activity and economic growth.

I see economics and sustainability as courses my students need to become managers, accountants, human resource experts, financial experts or marketing experts. So, I want them to learn skills to evaluate real situations and make analytical decisions in their own fields of interest. It is already recognized in the literature of teaching economics and STEM+ subjects that playing games in the classroom is one of the most effective teaching tool to engage students and generate deeper learning of complex concepts. I had become interested in games two years ago and now I am an advocate to make one step further by asking students to create their own games. Playing a game designed by the professor is great but creating their own games using economics and sustainability concepts brings them to an even superior level of understanding, knowledge and skills (excel, powerpoint, teamwork, creativity skills). I found this strategy very effective in economics and sustainability courses and would like to incorporate geosciences concepts in both games that I play in the classroom and games developed by students too.

Ed Barbanell, Philosophy, University of Utah

Modeling Interdisciplinarity

Any sensible discussion about "sustainability" must, by its very nature, be inclusive, requiring interactive dialogues with a broad array people about a great variety of things over a long period of time. For students to be able to mature into citizens who are actively engaged in such open-textured, multi-disciplinary dialogues, we must show them what those dialogues look like: as educators, we are the ones who have to model for them how reasonable people from academia, public service and private enterprise can talk with one another, respectfully disagree with each other, and, ultimately,

reach some consensus about what we want the world to look like and how we should go about making that happen. Therefore, the interaction between the instructors who are leading interdisciplinary class discussions is a critical activity for enhancing communication among students from different disciplines. Effective multidisciplinary team teaching requires developing a relationship, both personally and professionally, between the instructors. I am fortunate to have had great success co-teaching a course on water sustainability in the American West with a colleague who is from a discipline – civil engineering – that is about as far removed from mine – philosophy – as one could imagine. Our success is a product of a lot of work and luck. The work is not the kind that most faculty traditionally do, which is consistently interacting collegially with someone well outside their academic discipline. The two of us have been in regular and varied forms of contact over the last four years, and in almost every encounter, the subject of this course has come up. Formally, we met consistently for months, and we email each other regularly about ideas we had or articles we read. The luck involved here is that ours is a partnership about something that we are both passionate about, both personally and intellectually. We have found a particularly appealing outlet in a hungry and ready audience, one that craves an interdisciplinary conversation about something as fascinating and timely as water. We happened to be in the right place at the right time. So, simple as it sounds, any successful strategy for integrating the geosciences into a broader, interdisciplinary discussion about sustainability entails first simply getting geo-scientists interacting on a regular basis with their colleagues in other departments and colleges.

Thomas Beery, Center for Environmental Education, University of Minnesota-Duluth

Making Sustainability Visible

Sustainability is about people and the choices they make, ultimately it is a question of human behavior. A deliberate effort to demystify sustainability via open and critical awareness is an essential part of my role as an environmental educator. Choices in regard to sustainability can often be presented as problems to be solved with the acknowledgement of multiple correct answers; modeling is not about presenting one right way, it is about presenting a thoughtful or deliberate way. The power such a problem solving can be the motivational energy it generates, the alternate possibility that it inspires, and the behavior that results. In the spirit of illuminating everyday or 'regular' sustainability decisions, I will present one example from my role as an educator.

An environmental and outdoor education program brings the challenge of logistics into the question of sustainability and the classroom—our classroom is outdoors, sometimes right outside the door, sometimes across town, and sometimes it may be half-way across the country. One introductory outdoor education course offered at the University of Minnesota Duluth uses the Boundary Waters Canoe Area Wilderness as our classroom; we spend a weekend in the autumn camping and paddling in this unique setting. To engage 50 people in this effort and stay true to the planned outcomes of the experience, a great deal of logistical planning is necessitated. Much of this involves questions of sustainability, transportation, trip expense, costs, Leave No Trace planning, gear preparation, etc. Consider transportation—one school bus w/trailer or 12 cars to move 50 people? Along with the actual transport of students, a bus must make two seemingly wasteful trips (an empty trip back from the drop off and return empty for the pick up). The total bus fuel expenditure is approximately: 1 bus x 400 miles/8 mpg = a total of 50 gallons. In contrast, the cars making a direct up and back trip, the equation is: 12 vehicles x 200 miles/25 mpg = a total of 96 gallons for the trip. This comparison, using averages and approximates, presents a strong case for the bus; however, a simple comparison of fuel use does not go far enough. Other values, such as keeping students together, avoiding vehicle problems, risk management for 12 student vehicles vs. 1 professional driver and vehicle, etc. all factor into a decision. When the details are presented, the sustainability decisions such as bus vs. cars can be addressed and discussed. Students can learn from such a decision.

This example is meant to illustrate that careful decision-making about our shared education experiences may provide lessons in sustainability beyond the actual content of our courses. Illuminating such decision-making can allow educators to promote sustainability awareness without advocacy. We can use such decisions to encourage students to think critically about environmental behavior and further, to consider how their own decisions may be a part of sustainability.

Stephen K. Boss, Environmental Dynamics, University of Arkansas Main Campus

Fundamentals of Sustainability at the University of Arkansas - Emphasizing Institutional Strengths

Fundamentals of Sustainability is an interdisciplinary course designed to introduce undergraduate students to basic concepts and theories of sustainability at global, regional and local levels. The course is organized around four major thematic areas of sustainability: social systems, natural systems, managed systems (business and agriculture), and built systems (architecture and engineering) emphasizing academic strengths of the University of Arkansas.

The aim of this course is to increase the environmental literacy of students and pave the way for both the creative and persistent engagement of sustainability concerns into the students' own disciplines.

Social Systems
Gives an overview concerning who, what, how, and why behind specific social behaviors and dynamics leading to the global environmental crisis. Theories of social justice and equity are reviewed with a focus on how to improve sustainability for future outcomes. This section will also look at the relationship between social inequality (resource allocation) and sustainability. This uneven distribution of resources impacts certain subgroups more than others; particular attention will be paid to discussing the effects of unequal resource distribution on the poor, indigenous, racial/ethnic minorities, women, and the place-bound in both urban and rural areas.

Natural Systems
Provides a modern contextual view of Earth as a closed system with respect to matter and development of concepts of material transfers among various components of the Earth System (atmosphere, hydrosphere, geosphere, biosphere). Emphasis is on developing fundamental understanding of systems science, material transfers and mass balance as a means of understanding complex Earth processes. Introduction to the importance of quantitative measures to document environmental change as well as progress toward or retreat from sustainability will be provided. Interconnectedness of Earth processes and implications of interactions among Earth systems will also be discussed.

Built Systems
Focuses on the adverse effect that design and construction of buildings, with related infrastructure, have on the preservation of natural resources and quality of the environment. In this part of the course, we address the sustainable theories and concepts in the context of the built world, with the promise that they hold in shaping a better environment, and in changing our views on human-nature relations. Three broad topics will be addressed in the following sequence: regional planning and land use considerations, site-landscape planning, and sustainable design principles for the production of buildings.

Managed Systems
Addresses foundations of life cycle analysis, agricultural production-distribution mechanisms, customer good production, business, law and policy. The evolution of agricultural systems and the foundations of agricultural practices for meeting sustainability objectives will be examined. Business foundations for sustainability will be covered, including ethics, the role of consumer preferences and the optimization of sustainability objectives throughout the supply chain.

Steve Burian, Civil & Environmental Engineering, University of Utah

Value of Co-Teaching, Project-Based Learning, and Common Communication for Teaching Sustainability to an Interdisciplinary Class

Teaching sustainability to students from different disciplines requires new approaches to course planning, lesson planning, pedagogy, student expectations, and assessment. In the past five years I have had a small amount of experience in each of these areas through the delivery of three different courses. In addition, I have co-authored papers assessing the approaches and presented them at the American Society for Engineering Education (ASEE) annual conferences since 2008. The purpose of this essay is to pull from these past experiences to highlight techniques that succeeded, identify techniques that failed, and reflect with my current insight. Given my engineering disciplinary focus (although all interactions described below are interdisciplinary), the essay is written from the perspective of engineering educator.

Interdisciplinary teaching and learning of sustainability topics is enhanced through co-teaching. And a key element is the involvement al instructors in the planning of the course and lesson activities. I have co-taught three courses and in each case the interaction with my partners was essential in creating a course plan that could appeal to a broad audience, represented our collective teaching styles, and provided a coherent sequence of topics and lesson activities for the students. In all courses classroom activity has included significant discussion time and this is where the co-teaching is essential to an interdisciplinary set of students – to provide them role models of disciplinary people going beyond their discipline to take a fresh perspective and appreciating the perspective of others in different disciplines. This is especially essential if the disciplines of the students are disparate (engineering, science, humanities, and social sciences) where pre-conceived notions of the other majors inhibits respect/value of opinions initially.

Teaching sustainability to an interdisciplinary course is enhanced with project-based learning. My experiences of interdisciplinary teaching have included both project-based learning experiences and traditional classroom activities. Using projects enables the instructor (or instructor team) to set the scope of the projects to require a range of disciplines to illustrate not only real-world projects, but also the value of other disciplines. I have found students will learn well from each other (even from disparate disciplines) if there is a project integrating their efforts. Sustainability projects come in many shapes and sizes but the need for a range of disciplines can nearly always be found. Finding ways to integrate engineers with natural scientists with social scientists is a challenge, but accomplishing it with a project-based experience has worked well for me.

Establishing a common language and expectation level is essential for teaching sustainability to an interdisciplinary group. I have students from different disciplines and from different backgrounds will entre and have different thoughts on what is the expected workload, what is the expected quality of work, and how they communicate their thoughts. It is important to bring the entire class to a common ground and the key is communication from the instructors to set the course expectations. The instructors must role model working through communication and perspective differences. The instructors must make explicit the expectations and continuously reinforce them. And the instructors must work with students to prepare homework and project submittals to match a common structure that meshes the different disciplines and forces students to incorporate approaches and ideas from different disciplines.

Overall, I have found a key element to effective teaching of sustainability to an interdisciplinary group is to be extremely adaptive and adjust course content, teaching techniques, and expectations as the course progresses. I have rarely had to do this for a Civil Engineering course, even when offered for the first time. But I have had to do it for my interdisciplinary sustainability courses, even those that I have taught multiple times.

Morris Coats, Management, Marketing and Business Administration, Nicholls State University

One economist's approach to interdisciplinary teaching and exploration of sustainability

"The Theory of Economics does not furnish a body of settled conclusions immediately applicable to policy. It is a method rather than a doctrine, an apparatus of mind, a technique of thinking which helps its possessor to draw correct conclusions". John Maynard Keynes

"The economists' stock-in-trade -- their tools -- lies in their ability and proclivity to think about all questions in terms of alternatives. The truth judgment of the moralist, which says that something is either wholly right or wholly wrong, is foreign to them. The win-lose, yes-no discussion of politics is not within purview. They do not recognize the either-or, the all-or-nothing, situation as their own. Theirs is not the world of the mutually exclusives. Instead, it is the world of adjustment, of coordinated conflict, of mutual gains". James M.Buchanan (1986 Economics Nobel Laureate, not the 15th U.S. president)

An interdisciplinary approach to both research and teaching seems natural. Our departmentalized organization of education, while necessary for administration, seems to have led to a great deal of compartmentalized thinking. I was drawn to my own discipline, economics, because it is less about particular subject matter (though it does concentrate on society and social systems) and more of how one approaches that subject, the method of analysis.

For an economist, concerns about sustainability are at the root of the discipline. Economics is most commonly defined as the study of how humans act (and interact) in the face of scarcity of resources. To economists, all resources are scarce, just in different degrees. One of the earliest contributors to modern economics, Thomas Malthus, was concerned with the conflict between the exponential growth of human populations and the linear growth in food production.

In my own research, I have examined how the adoption of the secret ballot affected turnout in British Parliamentary elections, how school boards choose to have special elections for taxes to increase the chance of the tax passing, and how human social institutions, such as private property rights vs. open access, can lead to sustainability of the renewable resources or societal collapse.

Rather naturally, my research and teaching interests are interwoven, as well. Besides teaching basic introductory courses at my institution, I teach, three upper-level courses, health-care economics, public-sector economics and environmental economics.

While there is some tendency of students to compartmentalize knowledge, they do have some prior knowledge of areas outside of economics, and as an instructor, I find it useful to leverage that prior knowledge to introduce a concept that is new to them. For instance, many students taking introductory economics have had an introductory psychology class. I try to leverage their familiarity with Maslow's hierarchy of needs, to get them to understand that human wants are limitless. When teaching the time value of money, I draw upon their knowledge of the potency of deferred vs. immediate gratification. I also draw upon their mathematical knowledge of slopes or rates of change and optimization to issues of profit maximization and cost minimization issues. Since most students have had at least high school chemistry or physical science, I use the gas laws to illustrate the difference between changing a variable and changing a relationship. Competition as a process (rather than a state of affairs) is an evolutionary process and so an understanding of how one species becomes dominant in a particular biogeographical area or comes to share that area with other species is helpful in understanding the competitive process.

In addition to using prior knowledge to leverage learning of new concepts, similar leveraging is useful in terms of interest or curiosity. Many students have little innate interest in economics, mistakenly thinking that economics is only about issues such as international trade, inflation, or investing. A personal interest in healthcare issues, such as why their aunt cannot get her chemotherapy at the proper time because of current shortages can become an interest in economics if they learn in an economics class as why those shortages exist.

My primary examination of geosciences and sustainability are in the area of how different institutions and human behaviors lead to overuse and depletion or to more sustained access to key resources across generations. My research and teaching about the collapse of Easter Island, a useful metaphor for the earth itself, examines how open access rather than private property rights or other institutions (note the work of Elinor Ostrom on this) may prevent this sort of

societal collapse. Similarly, non-renewable resources can be protected from overuse through limiting access with individual property rights and the actions speculators. One new area for me to examine both in teaching and in research is the sustainability of natural resources and the preservation of natural resource wealth for future generations using democratic institutions to
control their use.

Brooke Crowley, Geology and Anthropology, University of Cincinnati

Instilling a sense of sustainability in a large introductory course

My philosophy has been defined both by my experiences as an instructor and as a student. I am fortunate to have been strongly influenced by exceptional professors and mentors throughout my academic career. In turn, it is my goal to inspire and encourage students. I have just finished teaching a course called "Humans and Nature: Living in the Anthropocene". Everything about this course was interdisciplinary. Half of my students signed up for an Anthropology course and half signed up for a Geology course. We covered a broad spectrum of topics including geologic time, atmospheric and oceanic circulation, domestication and the agricultural revolution, urbanism, environmental impacts associated with our modern lifestyles, and solutions for a sustainable future. Many of these topics have had a significant impact on my own life and are responsible for my initial desire to go into academia and teach. I developed my lesson plan from scratch. Readings included chapters from several textbooks, articles and popular readings. I incorporated a sense of stewardship and sustainability in this course. Course assignments were designed to teach students real world lessons. For example, I asked students to calculate their ecological footprints and their water use, and to keep a journal about what they consumed for a week.

I endeavored to gets students as involved as possible in this large lecture course. For example, I asked students to discuss questions in small groups and then report back to the class. I also created low stakes writing assignments to help students start writing down their thoughts without worrying about a grade. Students were given a thought question (i.e. "what is nature") and asked to write their response for 5-10 minutes. Volunteers then shared what they wrote. Responses were not graded but counted towards attendance and participation. In addition to these more formal participation activities, I frequently asked both directed and open-ended questions to the class at large and invited discussion. About 1/5 of the students regularly participated in class. One student even gave a guest presentation about his internship at Duke Energy. Several students who did not vocally participate in class posted links to articles and videos that related to course material. I was repeatedly impressed with what the students shared. Their insights will be incorporated into future course material.

Student feedback at the end of the course was rewarding. When asked what they would do with the knowledge they gained in my course, students listed various energy, water and resource saving techniques. Additionally, they expressed an interest in passing this information on to others: "We will share sustainable strategies with our friends, families and the new people we meet and instill a change in them". Based on my interactions with the students in my class, I believe that many of them will, indeed, follow through with these plans. Several students approached me about starting compost bins or using rain barrels at home and one student boldly declared to me that she had decided to become an ambassador for the Earth.

I am pleased with how this course went but I think that there is definitely room for improvement. For example, I would very much like to get students more involved with the local community. I would also like to include more variety in my class exercises. I am excited to share my experiences and to learn about additional teaching strategies from other workshop participants.

Benjamin Cuker, Marine and Environmental Science, Hampton University

Eating for a Healthy You and a Sustainable Planet

For the last three years I have co-taught an honors seminar called "Eating for A Healthy You and a Sustainable Planet." I teach the course with a colleague who has a degree in nutrition and who is chair of the Department of Biological Sciences (and formerly appointed in the School of Nursing). The 8 – 11 students represent the diversity of majors on campus. Most of the students begin more interested in the "Healthy You" part of the class than the "Sustainable Planet" component. However, by the end of the class they see that healthy diet choices coincide with sustainable agricultural and fair-labor practices. This comprehension comes from examining; nutrition, economics, marketing, geo-politics, endocrinology, ecological principles, economics, colonialism, industrial agriculture, organic farming, ethnic differences, medicine, and history.

We use an active learning approach that gives ownership to the students. We begin by having the students view (on their own) some recent films (Food Inc., Super Size Me, and Fast Food Nation), and have them bring questions for discussion to class. Next the students keep a photographic food diary of every item they eat or drink over a three day period. They also enter that data into the online USDA MyPlate.gov and create a nutritional report. The students create a powepoint using collages of the food pictures for each day. This facilitates a discussion on what they are eating, its nutritional value, and environmental consequences.

Students must sign-up to give two 10 minute presentations on questions from a list formulated by the professors. Example questions include: What is meant by the statement that people of African descent in the Americas are twice enslaved by sugar? What is/was the role of the sacred cow of India and how has that been changed by the Green Revolution? What is the environmental and health impact of industrial beef production? What are the benefits of choosing a vegetarian diet?

The students also do (as teams or individuals) a service learning project and report (PowerPoint and paper) on that to the class at the end of the semester. Examples include; serving meals at a soup kitchen and evaluating the efficacy of the menu, contrasting food availability in a poor and wealthy neighborhood, surveying shopping cart choices and correlating those to perceived BMI scores of shoppers.

We make extensive use of BlackBoard to facilitate communication and host readings and videos. Typically twice a week we send to the class current news items (text and video) related to the course objectives. This keeps the material fresh.

The capstone event is a vegetarian meal they help prepare at my house. The old (1936) house is near energy neutral (we use solar PV in a grid-tied system to make 120% of our annual electricity needs, have solar hot water, a solar heat wall) so they get to also see the possibility living sustainably.

Scott Cummings, Chemistry, Kenyon College

The imperative for chemists to teach about sustainability

Chemistry plays a central role in many of the global and local aspects of sustainability: with problems of continued dependence on fossil fuels, and with the promise of new types of clean and renewable energy systems; with the production of toxins that pollute our water, soil, and air, and with new technologies for detecting and remediating pollutants in the environment; with wasteful and resource-depleting manufacturing, and with the design of new recyclable materials and "green chemistry" processes. A rapidly emerging green sensibility is transforming business, policy, the marketplace, and some aspects of higher education.

Our undergraduate chemistry curriculum seems to be lagging behind the constituents at either end of our bailiwick. Incoming college students are bringing to our campuses a new level of enthusiasm and passion for issues of sustainability and the environment. And paths out of college are leading into a rapidly changing career environment, in which graduate research laboratories and businesses in the chemical sector are shifting their focus toward the science and products to serve a society seeking a more sustainable path. Surprisingly, even sustainability initiatives in college operations may be ahead of curricular change.

To be sure, some chemists are employing diverse and creative approaches to teach about sustainability, at institutions ranging from vocational colleges to research universities and with students studying science, the liberal arts, and business. Some of this is happening through new instructional units and laboratory experiments on specific topics such as water pollution, synthesis of biofuels, greenhouse gas emissions, photovoltaic materials and toxicology. In other institutions, entire courses have been re-designed to emphasize sustainability or one aspect of it. The most ambitious efforts have built new academic programs and degree paths in sustainability.

But these are nascent initiatives. Even a cursory look through the leading college chemistry textbooks would suggest that the general state of chemistry education--at best--is making modest green redesigns to an established formula (adding "little boxes" to the textbooks), or--at worst--is ignoring this important change altogether.

The sometimes overused (and occasionally abused) term "sustainability" deserves a healthy dose of skepticism. Advertising Age listed "sustainability" as one of the "jargoniest jargon" words of 2010, and a 2009 article in Scientific American on the top-10 myths of sustainability noted that "even advocates for more responsible, environmentally benign ways of life harbor misunderstandings of what 'sustainability' is all about." Viewing sustainability as being about survivability offers one focus. The ubiquity and gravity of the problems facing our planet and societies—and the valuable role that chemistry can play in seeking solutions or responses to those problems—indicate that the ways chemists will be employed to serve society are changing fundamentally. To remain relevant, chemistry education must adapt.

Chemistry will be central to developing clean energy systems; to designing advanced materials for improving energy efficiency, made from renewable feedstocks, and able to be recycled; to inventing new ways of detecting and removing pollutants from water, air, and soil; to designing new approaches for sustainable agriculture and biofuels; and to creating new diagnostics and treatments for a sustainable health care system. Many of these topics already have a natural overlap with much of the undergraduate chemistry curriculum.

So while the imperative to teach about the chemistry of sustainability becomes more clear, how we might do this remains a challenge for college chemistry faculty. What are the critical chemistry-related sustainability topics? Which content and process skills are essential for new career paths? Must we add new content to an already-crowded curriculum? How will revising existing courses affect the integrated structure of a departmental curriculum? What resources could help support faculty interested in working on this transition? Answers to these questions will emerge from continued discussion within the chemistry community about ways to incorporate sustainability topics in our curricula, and by sharing ideas, examples, and materials with educators in other disciplines.

Mary Ann Cunningham, Earth Science and Geography, Vassar College

Questions about application, theory, and engagement with sustainability

The issues that currently puzzle me about teaching sustainability are (1) what seems like a gulf between those who are enthusiastic and those who aren't, and (2) the ideological distance between theory and practice in the classroom. These are probably very closely related questions. By the gulf between enthusiasts and others, I mean that issues of sustainability are patently obvious and intriguing for some of us. But for others there seems to be resistance to the idea of giving much attention to sustainability. I don't know why, maybe because the topic is trendy or worldly or hippie or socialist, or it's a group identity issue (they're not that kind of people), or it may just be that we academics don't like to

be told what we ought to do. In any case, at my institution there's rather tepid support in some quarters for teaching sustainability, it seems to me. I think as a consequence it has been a struggle to implement examples of sustainable practices, and I think our students leave with less preparation to do good for society than they should have. Sometimes we squander a chance to seize their enthusiasm. And I think we lose the opportunity to instill in them a forward-thinking sense of possibility.

A second and related puzzle for me is the apparent perception of a gap between practical and theoretical courses. In my mind, theory and practice go hand in hand—that is, practice keeps the theory real and theory keeps the practice interesting—but I hear faculty and their students talking as though the two were unrelated worldviews. It may be that sustainability is too broad (that is, too multidisciplinary) to be seen as having a solid theoretical core (or canon). Or it may be that today's faculty just didn't grow up studying sustainability—which underscores the importance of teaching it now. Like climate change, sustainability is inherently multidisciplinary, but that doesn't mean that multiple disciplines find it in their immediate interest to engage the ideas. My department of Earth Science and Geography is one of the main exceptions to that, and a substantial proportion of our courses have sustainability in the titles and course descriptions. But I think as an institution we could do a better job to clarify and make visible courses in sustainability. Perhaps what is needed are some general theories of sustainability that we could offer in order to expand the respectability and visibility and intellectual relevance of themes in sustainability.

I suppose in terms of my teaching about sustainability in a multidisciplinary context, multidisciplinarity comes rather automatically in geography. (Which is to say that in geography it's generally legitimate to draw on ideas from multiple disciplines as we explore why places and regions are as they are, and why they differ.) I teach a variety of environmentally-oriented courses in geography, such as conservation, sustainable landscapes, environment and land use planning, food and farming, GIS, and next year environmental science. Most of these courses are cross-listed in at least two, sometimes three or four programs. I generally have students enter the central topic from whichever perspective they find useful. They take on project topics that explore issues relevant to their various majors, and I try to make them teach each other as much as possible, so that the relationships among issues are obvious. Like climate change, again, sustainability is an issue that transcends disciplines and belongs to everybody, so taking multiple perspectives on a common problem, such as land use planning or food production, makes sense to students as well as to me.

Becca Paulsen Edwards, Department of Physics, Southwestern University

Sustainability Education within an Earth Science Course at a Small Liberal Arts Institution

One of the benefits of teaching at a liberal arts college is the diverse makeup of the students in each class. Teaching these students, who are largely non-scientists, an environmental studies course is an opportunity to generate balanced and educated thinking on issues of environmental sustainability. Even though many of these students are not headed to scientific fields, their knowledge of geoscience will enable them to make more informed decisions as citizens and future leaders. This sort of interdisciplinary understanding is critical to addressing the policy-science conflicts so prevalent in the current political climate.

When teaching an interdisciplinary science course to a diverse group of students it is of primary importance to maintain the rigor of the science component of the course by maintaining high expectations of the students in the area of background reading, class participation, and lecture attendance. In addition to placing heavy emphasis on understanding the scientific part of the curriculum, it is important to build in multiple opportunities for the students to apply their scientific understanding to interdisciplinary issues of environmental sustainability. Most of the students in the most recent offering of this course had an interest in environmental policy, so issues of sustainability were particularly interesting to them. For example, during our unit on stream flow, we discussed the natural processes associated with river flooding and delta building. Once the students were comfortable with that material, I was able to devote some

time to discussing how the interruption of those natural processes have led to the deterioration of the wetlands in South Louisiana and the subsidence of the land in New Orleans. Later in the semester, after the students learned about the meteorology of hurricanes and tropical storms, they continued the discussion of New Orleans vulnerability to storm surge. Again, the discussion was framed as both a scientific and political issue, with a heavy emphasis on what should be done going forward from an environmental sustainability standpoint. Another example of combining geoscience material with a sustainability focus is our discussion on hydraulic fracturing. After watching a PBS Frontline documentary on hydraulic fracturing, the students discussed the benefits of natural gas as a cleaner alternative to burning coal for electricity generation. Then they discussed whether those benefits justified the risks of hydraulic fracturing, with all its associated environmental sustainability concerns (groundwater contamination, alteration of topography, etc). The diverse classroom makeup has been invaluable when having classroom discussions about the inherently interdisciplinary topics unique to an Earth Science course, including government response to Hurricane Katrina, and Global Climate Change in addition to the ones mentioned above. It has been a source of great enjoyment to hear, for example, a sociology student tie together the both hard science he has learned in the course and his own thoughts on the treatment of the poor population of New Orleans following Hurricane Katrina.

The students were motivated to learn the scientific fundamentals that made up the bulk of the curriculum by their interest in sustainability and environmental policy. By building in opportunities for them to synthesize the new scientific material with their background knowledge and interests in current environmental issues, the students were able to develop a scientifically accurate and balanced point of view on a number of issues of environmental sustainability. It is my hope that their experience in the Earth Science class will inspire them to approach decision making from a place of scientific understanding and not political bias.

Holly Ewing, Environmental Studies, Bates College

Credibility as a Challenge in the Integration of Science and Sustainability

I teach interdisciplinary courses in the sciences (combining geology, ecology, and chemistry) within an environmental studies program, and I would describe my teaching as being primarily about interdisciplinary science and not sustainability. There is now a push on campus to connect the curriculum to sustainability initiatives, and of course everyone is looking to Environmental Studies for that leadership. And yet, I do not think of myself as teaching sustainability science, and I resist such descriptions by others—even though I know that the long-term viability of ecological, economic, cultural, and social systems may well rest in part on our ability to effectively draw on scientific understanding as we set policies and make choices. Why is it that I, as a now-tenured faculty member who no longer has to convince colleagues in traditional science departments that I really do science, still resist coupling science and sustainability? The short answer involves the same word that I might have used pre-tenure: credibility. That is, I am still negotiating how it is that we have conversations about the practice and role of science in sustainability initiatives and how we help non-scientists understand the subjectivity and uncertainty inherent in science as part of our credibility rather than as a threat to it. Here I reflect briefly on two dimensions of credibility in science: context and uncertainty.

To help students engage in discussions of the role of science in realms that can be controversial—for example, conservation, sustainability, and policy—I present science as one of the many subjective human endeavors. That is, I begin by placing science in the context of human activity—that we must make choices as scientists about what questions we ask, how we go about sampling to answer those questions, and how we analyze and interpret data. Science is fallible and is only as good as the process, and yet when done well, it can provide an important perspective and essential understanding as we think about the choices we make in other arenas. From the scientist's perspective the context includes the importance of doing science through established, repeatable, and to the extent possible "unbiased" methods to answer questions rather than simply to reinforce an opinion. Since this method is part of what I perceive to give science credibility in the public sphere, I tend to err on the side of teaching the tools, methods, and habits of the mind behind the scientific study of systems and secondarily some of the understanding of the structure and function of

ecological systems such science has revealed.

In teaching scientific approaches to understanding systems, I have grappled with how best to deal with uncertainty—a topic difficult for students and a substantial part of what I consider to be ill-informed public dialogue about what science does or does not say about topics such as climatic change. Any practicing scientist knows that there are many kinds of uncertainty. Those stemming from measurement error and inherent variability in systems are usually the first to come to mind. But there are also those that come from the way in which we chose to measure—our choices of methods and the spatial and temporal extent of our sampling (as constrained by access, time, money, and our own conceptions of the world—part of the aforementioned subjectivity). Despite my ease at recognizing sources of uncertainty in my own and others' work and my comfort with the scientific endeavor of interpretation in the face of uncertainty, I have found uncertainty difficult for students. How is uncertainty manifest in scientific studies? How it is displayed in graphs? Where does it change an "answer" or interpretation? And where, despite uncertainty, are there still conclusions that can be defended? Discussing these things can be difficult in introductory courses where I can assume no statistical background and have a substantial portion of the class that is afraid of anything numerical. I have found that graphical representation of information—both data students generate and data from other sources (e.g., the results of different model simulations as portrayed in the IPCC report)—is the easiest avenue into the material for students who are not quantitatively inclined. The challenge, though, even with graphical approaches is helping students come to an understanding of how and when an interpretation can be made (and what such an interpretation might be) when data are variable.

Benjamin Fackler-Adams, Physical Sciences, Skagit Valley College

Sustainability: The Key To Student Engagement

As an "Instructor of Interdisciplinary Science" at a community college that teaches numerous interdisciplinary, team-taught learning communities each year, I have had a lot of opportunity to explore teaching sustainability in a variety of contexts. The hugely interdisciplinary nature of sustainability offers a lot of opportunity for engaging activities and courses. I have worked throughout my career to incorporate concepts of sustainability into geoscience and chemistry courses, and am currently focusing on expanding the sustainability strand in all classes that address the natural world or science in a societal context (e.g. Physical Geology, Oceanography, Environmental Geology, Geology of the Pacific Northwest, Chemistry Concepts, and Eastern & Western WA Field Study).
Examples of interdisciplinary course I have taught that foster understanding of sustainability include:
Pathways To Sustainability (Chemistry Concepts & Global Issues): In this class we explore the scientific, social, economic and political aspects of problems associated with our cultures reliance on energy and food (e.g. air pollution, global climate change, ecosystem degradation, nuclear waste). The students engage in major group projects and presentations analyzing current and emerging sustainable practices in transportation, electricity generation & distribution, and food at local, regional, and global scales. A description of this course is posted as part of the Curriculum for the Bioregion curriculum collection on the SERC site, which will go public in late August.

Earth Exposition (Environmental Geology & English): When teaching environmental geology I strive to place geologic hazards and Earth resources in the context of human choices that are or are not sustainable from risk, resource use, and Earth System perspectives. For example, approximately the later third of the class is spent on a unit exploring the relationships among energy resources, mineral resources, waste management, and global climate change. Students read Elizabeth Kolbert's book "Field Notes From A Catastrophe", write a term paper on human response to climate change, and develop a group presentation (e.g. poster, slide show or web site) that synthesizes the findings of all group member's essays. A description of this course will be part of this workshop course collection.

Diving Into Oceanography (Oceanography & English): This course has a similar format to Earth Exposition (above; i.e. writing intensive) but includes a major unit exploring the relationship between humans and the Salish Sea (a name

applied to recognize that the Puget Sound (USA) and Strait of Georgia (CA) are one system). Students read "State of the Sound 2009", and apply what they have learned in the class about the inter-relationships among the geo-, hydro-, bio-, and atmosphere to understanding how human activities impact the integrity of the Salish Sea system, and degrade its ability to provide essential ecosystem services.

Strategies I have used to foster interdisciplinary learning include: (1) the exploration of sustainable practices at various scales as described above for the Pathways learning community, (2) comparison of the nature of scientific explanations and the structure of academic theses and their support in essays in classes where science and English composition were linked, (3) reflective writing assignments asking students to compare and contrast the nature of geologic processes and ceramics techniques in a Geology and Ceramics learning community. Another important strategy is to find overarching concepts like Systems or Energy whose meaningful exploration requires multiple perspectives (e.g. Earth System approach in Diving Into Oceanography above).

The most important consideration is designing a course or activity from my perspective is to use findings from cognitive research (e.g. "How People Learn" http://www.nap.edu/openbook.php?record_id=9457&page=10) which shows that deep, enduring learning requires three components: (1) prior conceptions on a subject must be engaged in order for new learning to be integrated with existing knowledge, (2) students must build their own understanding of a concept/topic with hands-on activities, and (3) reflection on the learning process and specifically where their existing knowledge was challenged or changed is critical to long-term retention and the ability to apply new knowledge in different contexts. Consequently, it is critical that activities and courses as a whole provide students with as much opportunity as possible to record and discuss their initial ideas, to collect and interpret evidence, and engage in personal and group reflection on the significance of a particular activity or the overarching themes of a course as a whole.

The most significant challenge to realizing the benefits of interdisciplinary learning on the topic of sustainability, in my experience, is how to provide room in the course schedule to do a meaningful job of exploring the sustainability themes. For example, adding a sustainability strand to an Environmental Geology course means that there is less time to develop the traditional content of the course. Many geology and chemistry textbooks are, however, finding ways to weave in sustainability while minimizing the impact on traditionally important topics as well as exploring significant connections with aspects of sustainability. One example of this is the impact of population growth on the risk presented by geologic hazards (e.g. earthquakes, volcanism).

Exploring human choices that are- or are not sustainable from geologic hazard, resource use, and Earth System perspectives offer significant opportunity for integration of geoscience concepts with sustainability. Social science concepts like population dynamics, affluenza, and the cultural & political context of global climate change are clear areas where significant connections between scientific and other disciplines can be exploited. Examples I have used in various classes include:
- When teaching Chemistry Concepts, for which I use the "Chemistry In Context: Applying Chemistry To Society" textbook, I focus on energy, climate change, and their societal context. I spend considerable time developing the concepts that understanding the climatic response of past forcings (insights gained via the geosciences) is the key to climate forecasts, and that the alarm on the part of scientists to global climate change is evidence-based.

- In environmental geology, I have students read the introduction to "Cradle-To-Cradle: Rethinking the Way We Make Things" by McDonough & Braungart (North Point Press, 2002), view The Story Of Electronics (http://www.storyofstuff.org/movies-all/story-of-electronics/), and do a lab where they perform a life cycle analysis of the sources and fate of the materials in a cell phone. This exercise is modeled after and includes elements of "Computer Chip Thermochemistry: How Can We Create an Integrated Circuit From Sand?" from the chemconnections series.

- In many of my classes I have students keep a waste journal for a week and estimate how much waste they generate in a year, where it goes, and what land-use, climate, and mineral resource impacts/implications their habits have. I have posted a description of this activity (titled Waste As A Resource) as part of the Curriculum for the Bioregion curriculum collection on the SERC site, which will go public in late May or early June in time for the InteGrate workshop.

- During the energy resources unit of environmental geology, chemistry concepts, and my energy and society seminar, I have students work through the Carbon Mitigation Initiatives Stabilization Wedge Game (http://cmi.princeton.edu/wedges/game.php) and write personal responses on the impact of the scenario on their understanding of the societal context of our resource use choices.

- I am currently using climate change as a through-going thread in my Geology of the Pacific Northwest class. I had my students read "A Human-induced Hothouse Climate" by Kidder & Worsley in the February 2012 issue of GSA Today. I'm building on this perspective by looking at mechanisms driving climate change in the past (orbital, tectonic, biochemical, etc.) and how, as stated in Kidder & Worsely (2012), our current activities rival these forcings.

- Part of my on-going work with the Chemistry For The Informed Citizen grant (NSF-CCLI) (described below) as been to develop a module that uses an exploration of climate modeling as a means of promoting understanding of the use of models and modeling in the sciences. This module has students read about and use ice –core data to model (forecast) the role of CO2 in future climate change.

In conclusion, the geosciences offer abundant opportunity to engage students in meaningful interdisciplinary learning that has real relevance to their lives. In light of the status of sustainability as arguably the most important issue of the 21st century, it would be a disservice to our students not to find as many means as possible to foster its understanding.

Lisa M.B. Harrington, Kansas State University, Geography

Approach and Challenges to a General Undergraduate Sustainability Science Course

I teach a mid- to upper-division course on sustainability, which I introduced as "Sustainability Science," oriented around the recommendation that such an interdisciplinary approach to sustainability and addressing of current global issues be established (e.g., Kates et al. 2001). My approach to teaching sustainability in broadly interdisciplinary undergraduate classes has been oriented around introduction of key concepts, including different ways of viewing the areas of attention for sustainability (typically given as environment, society, and economy), and historical attention to human-environment relations. I spend time devoted to coverage of current concerns related to sustainability, including explanation of climate change, the human role, and potential effects; I also utilize recent videos addressing issues like 'fracking,' peak oil, urban sprawl, city actions, and small business actions and innovations in support of more sustainable conditions.

Challenges for the course have included how to teach, in a general sense but with sufficient detail as to make ideas somewhat more meaningful and potentially tools that students can use later in their careers, concepts like life cycle assessment (LCA), the use of scenarios (e.g., as in the Millennium Ecosystem Assessment [MA]), and indicators (e.g., as applied in the Millennium Development Goals [MDGs]). I would particularly like to be able to incorporate more hands-on or service learning components in the course, but with the prospect of the class size growing to perhaps 100 in the next two-three years, I am not sure that this is practical.

Encouraging discussions, and basing some questions on what I know of students' majors, has helped to create learning with students as sources of information, and encourages student engagement and interdisciplinary learning. Use of three article review assignments, with an explicit requirement that students connect the articles' content to other course ideas and materials, is a way to address a need to create situations where students explore (and become more comfortable with exploring) relevant topics in the literature, integrate ideas and materials (potentially from different disciplinary perspectives), and apply critical thinking. Incorporating videos into the class helps to add variety and interest to what is basically a 'lecture' style course.

Much of the material covered, including several of the videos, seem disheartening or 'depressing' to students. I've tried to alleviate this by concluding the course with the more positive applications of new ideas and business models oriented toward greater sustainability via videos and exploration of examples (often using online sources).

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Tracey Holloway, Nelson Institute for Environmental Studies, University of Wisconsin-Madison

How Should We Teach 'Sustainability Science'?

My main motivation for teaching sustainability is to promote solutions-oriented thinking about environmental challenges. Rather than focusing solely on the problems, we can empower students to evaluate solutions and become innovators. I've always been an optimist, and it is hard for me to focus on any issue – much less the future human existence! - without hope that it can be solved. My own path into environmental research came through applied math, into weather and climate, and then into global and regional air quality analysis. Along the way, I have seen that there are solutions – lots of them. I'd like to help students see opportunities to build a more sustainable world, and to have the analytic tools and frameworks to make informed decisions.

One problem about decision-making on sustainability is the complexity of the human and natural systems involved. Why does CO2 warm the climate, but SO2 impacts health? Why does fertilizer use in the Midwest impact water quality and biodiversity in the Gulf of Mexico? Unfortunately, most students don't get exposed to these cross-cutting issues until they are advanced in a particular major. Electrical engineers learn about energy systems; geologists learn about fossil fuel reserves; atmospheric scientists learn about climate change. Even then, students typically approach each issue from a deep disciplinary perspective.

Rather than the capstone on disciplinary expertise, I would like to see sustainability – even the quantitative, complex aspects of science and engineering – taught in an interdisciplinary manner at the undergraduate level. In my experience, students don't have to solve lots of equations to understand electricity systems or climate change. In fact, there are some basic tools – accessible with a few calculus concepts, or less, link together many major sustainability issues. In my framing of sustainability science (a work in progress) these include: back-of-the-envelope problem solving, systems dynamics, quantifying risk, life-cycle analysis, working across spatial and temporal scales, working with unfamiliar metrics (e.g. ppm, kWh, footprint, LEED), and utility of model-based data vs. measurement data.

At UW-Madison, I am developing a new course: "Introduction to Sustainability Science," geared toward 1st and 2nd year undergraduates. The course fulfills our physical science requirement (both in the College of Letters & Sciences, and in the recently launched Environmental Studies major), and aims to teach the quantitative skills noted above. I offered it once before – in Spring 2011 – and I will offer a new-and-improved version in Spring 2013. I am looking forward to the discussions at InTeGrate to help shape this new course.

Although I have serious goals in designing the course, I have given a lot of thought as to how to make classes fun and engaging for the students. Toward the fun aim, I include about 3 field trips – around campus or town – into the course. I ask guest speakers to talk both about issues in the class, and how these play out in their careers and life. I write homework problems that are (somewhat?) engaging: interactive role-playing software, NASA data sets, and campus-scale back-of-the-envelope problems. Where lecture is needed, I am trying out the recommended approach of Edward Tufte (http://tinyurl.com/yo9hw7). And, I grade on a cumulative point scale – hopefully reflective of students'

cumulative knowledge. I offer lots of extra credit options, almost exclusively tied into campus engagement – attending public lectures, participating in an innovation competition, touring campus research labs and posting a video summary. This approach allows me to grade homework and tests rigorously, while providing students the feeling that anyone can get an "A" with enough focus and work. As a last point, I'd really recommend the book is "Switch" by Chip and Dan Heath – it suggests creative approaches to leadership, many of which fit teaching well.

Meghann Jarchow, Interdepartmental - sustainability, University of South Dakota

Using process-focused assessments for teaching sustainability

Thinking about how we assess students is as important as the methods that we use to convey the course content. I think that most assessment methods (e.g. tests, quizzes, essays, projects) focus on the products created by the student (i.e. are goal oriented) rather than on the process that the students go through in completing the assessment. This end-product-focused method of assessment may discourage students from taking risks and may hinder their creativity. There are many benefits to these forms of assessments, however, including the fact that most of our careers are evaluated based on the products that we produce.

I am not advocating that we should get rid of assessments that evaluate students based on the products that they produce. Rather, I believe that we should also consider adding assessments that evaluate students based on the process that they go through in completing the assessment. This type of assessment could be beneficial for multiple reasons. First, it would encourage students to be mindful about the process that they are using in completing the assessment. Focus on process is important in sustainability-related issues because moving towards more sustainable systems includes developing and utilizing processes – in addition to end products – that are sustainable. Second, process-focused assessments could encourage students to be more creative and to take intellectual risks. At least from my own experience as a student, I was keenly aware that earning high grades had important ramifications for getting scholarships, getting into graduate (or professional) school, and finding a job. As a result of that, I would have been very hesitant to go beyond my developed skill sets on an assessment, which limited my opportunities for taking risks and being creative. Third, the assessment could be designed for all students to go through a similar process, but the products produced for the assessment could be highly variable, allowing the students greater freedom in completing the assessment.

Here I will give one example of a process-based assessment where students would be using systems thinking to assess and visualize a complex, sustainability-related issue, such as the effects of food on the environment and human health. In this example, the students would have been studying food systems for multiple weeks. As the students were reading and discussing the topic they would be told to focus on the interrelations and feedbacks related to the various issues within the topic – and other topics that feed into the topic at hand. A process-based assessment that could be used for this portion of the course (rather than an exam, for example) would be to develop a way to visualize this topic. The students could do this by developing a concept map, working through one case study in depth, using photographs to portray aspects of the topic, or whatever other method they came up with. Rather than being assessed on the product that they developed, which should be presented to the class in some form to show the class the diversity of ways of addressing an issue, the students would be assessed on the process that they went through to develop the product. For the assessment, the students could be asked – either in writing or verbally – to describe the process that they went through in deciding how to select the method that they did, what challenges they encountered when using the method that they selected, what benefits and limitations the method that they chose had compared to other methods that they considered (i.e. identify tradeoffs among methods), and what previously-developed skills did they utilize and what new skills did they have to develop.

Although there are likely to be problems with implementing process-focused assessments – including student

uncertainty – I think that it is worth considering and experimenting with other forms of student assessments because of their importance in implicitly telling students how they should address and solve problems.

Stephen Kissin, Geology, Lakehead University

Sustainability in Mining Activity

Northwestern Ontario is a vast area underlain by the Canadian Shield that has experienced mining activity for the past century and a half. The area, particularly the more northerly portions, is relatively unexplored by modern methods and has enormous mineral potential. The obvious sustainability concern is environmental sustainability; however, economic and social factors are also matters of concern.

Mining suffers from a poor public reputation. This can be attributed in part to "the sins of the fathers (and grandfathers)". It is possible to point out mining districts such as the Coeur d'Alene district of Idaho or the Sudbury district of Ontario where mining activities dating from the Nineteenth Century have left a legacy of environmental damage. How ever, we are hopefully in a more enlightened time in which mining operations are conducted in such a way as to preserve the environment.

Sustainability may also be considered in relation to the social effects of mining. The creation of one-industry town, particularly those that are geographically isolated, can result in social problems such as the provision of medical and educational services. /closure of a mine that supports the economy of a town may at worst leave residents without an economic basis of support and result in a complete loss in business and residential property values. Thus, the ultimate result is a ghost town. Sustainability requires foresight, either avoiding the creation of one-industry towns or planning for the survival of the town after mine closure.

Another social aspect of sustainability is the accommodation of resident populations, particularly indigenous peoples who have legal rights in various forms. Sustainability requires that these populations be part of the mining process at the outset.

Economic aspects of sustainability must also be considered. Mineral resources in general are scarce, and they are not randomly distributed. These resources are vital to the economic health of some regions, and the need for resources in a modern society is ever present. Land use must consider the mineral potential of an area before large tracts of land are closed to mining.

In consideration of the foregoing discussion, and with prospects of future mining developments in northwestern Ontario, Lakehead University is creating a Centre of Excellence in Mineral Exploration and Sustainable Mining Development. This centre will be located within the Department of Geology and will be headed by a Canada Research Chair. The participants will come from a variety of disciplines including biology, chemistry, anthropology, engineering and business as well as geology. We hope that this multidisciplinary approach will work to resolve problems of sustainable development.

David Kobilka, Earth Science, Central Lakes College-Brainerd

Geoscience is by its nature interdisciplinary

Geoscience classes, especially those with an environmental component, are by nature interdisciplinary. For example, introductory Oceanography involves topics in chemistry, physics, biology, and geology. A course in Natural Disasters is also about human behavior (psychology) and population dynamics and trends (human geography). I teach those subjects. Where possible we bring in guest speakers. There is almost always an activity on the topic. If the topic seems out of sync with the course in the eyes of the student, an understanding of the relevance of the topic to the course itself becomes a learning outcome for that section, and there will be an assessment that measures how well they made the connection. For example, in Natural Disasters it is common for students to not understand the connection between population growth and natural disaster events.

My approach to course design has eased over the years. Gone is a rigid adherence to a course semester plan. Geoscience, environment, and sustainability are so rich in current topics, that I see it as an injustice to students to not look at current events through a geoscience lens. If that means we miss out on one part of the spectrum of topics typical of a survey course then I see that as part of the cost of having an informed citizenry as an outcome for the course. So in Natural Disasters for example, we keep an eye on the news, and report out daily on events around the world. Most events only get brief mention, but occasionally there is a large event lasting months for which the victims of that event deserve our attention and compassion. The recent tsunami in Japan, flooding in Pakistan, earthquake in Haiti are not only news, but are so large that they affect all of us. They are also a direct and current application of the very science we are working through. Of course the event falls out of sync with the course plan – an earthquake strikes during the section on tornadoes. We switch gears because we have to: it is our duty as compassionate human beings. That requires everyone in my classes, not just me, to take a multi-disciplinary approach to our topics.

Is this approach effective as regards the standard rubric for geoscience understanding? Yes. I know because I assess, assess, assess. My students hand in something they have written almost every class period. Is that more work for me? Probably. My daily colleagues would tell you it is. But it has a number of advantages:

- It helps me to understand the ebb and flow of every course section every time we meet. When something is not working I know it right away and can adjust.
- It allows me to deviate from the survey model of an introductory class. If I want my students to know what is going on right now in the world in which they live, this is the way we get that done.
- It is more interesting for me. In requiring a class of 60 students to follow the news, there are 60 sets of eyes scanning the news: I get the details of events I might otherwise never learn about.

As a nascent teacher of topics in sustainability, the challenge I have encountered is like that of any new topic that is constantly changing; I have trouble keeping up. Sustainability, how it is perceived in the public and private spheres, and its state-of-the-art is changing fast. No textbook is adequate for that. Articles, videos, and news stories is how I keep up with it and how I expect my students to learn about it. And the tools for teaching and learning sustainability are just coming on line. I'm not inventing them myself. I choose to leave that to the experts.

Tracy Lai, Humanities/Social Sciences, Seattle Central Community College

Sustainability and Hanford Reach

The struggle over Hanford Reach, the last wild stretch of the Columbia River, is difficult to understand unless we take an interdisciplinary approach. Hanford Reach is a case study of colliding interest groups but the co-management, if there is to be such an approach, requires understanding the history, the science and the cultural conflicts over what is important and how to value what is still there.

An interdisciplinary approach would engage the scientific understanding of the delicate ecosystem in the region, as well as the science of nuclear wastes and the theory of toxic wastes clean-up. An historical approach would engage the

multiple histories told, remembered and recorded in the region from petroglyphs and sacred sites to diaries, news clippings, treaties and laws. An ethnic studies, anthropology and/or sociology approach would distinguish the multicultural perspectives that inform peoples' behaviors and approaches.

By employing a variety of disciplines, I hope to construct an approach that mirrors the complexity of the problems before us. As we consider Hanford Reach through various lenses, we should find nuances and intersections that might have remained hidden.

Using the approach of many voices, I would try to complement the reading material with speakers who can speak to parts of the picture. To put together these multiple sources, I would organize students into collaborative groups so that they can share and discuss their findings within their group and also with the class as a whole (note that history courses usually have 30-35 students enrolled).

We might examine public and private narratives about Hanford. For example, there are government (public) reports and findings about Hanford. Journalists and documentarians have also probed the topic. There are also testimonies by individuals who worked at Hanford reservation or whose homelands, such as members of the Wanapum Band, were impacted.

Would we need to interrogate whose ideas of sustainability are more valued? Is sustainability a universal concept? Ultimately, we must face issues of power in terms of who has the power to implement a vision of sustainability.

Andrew H. Fisher's *Shadow Tribe, the Making of Columbia River Indian Identity* opened my eyes to a much more fluid identity process than I had been aware of. The implications of this fluidity regarding which Indians are included in discussions, policy-making and funded initiatives is troubling. Simply stated, non-enrolled Indians (federally recognized) are once again disappeared. Although I have been thinking of sustainability in a more ecosystemic way, I'm left wondering about sustainability and endangered peoples/cultures.

In foregrounding sustainability in a Pacific Northwest History course, I hope to make history more present so that students may see themselves as intentionally choosing to be part of a larger environmental justice movement. Seven generations forward: how many of us really understand that phrase?

Derek Larson, Environmental Studies, The College of St. Benedict/St. John's University

Teaching Sustainability Through History

Our environmental studies department was created 20 years ago with the specific intention of interdisciplinarity in its design but due to resource constraints (i.e. few faculty trained in interdisciplinary methods) its curriculum remained largely disciplinary through its first decade. That changed in 2002, when we first developed an introductory course in environmental studies (ENVR 150: Introduction to Environmental Studies) that was explicitly interdisciplinary. Since then we've built a major and a department around the premise that environmental /sustainability problems in the real world can only be addressed through interdisciplinary approaches. Consequently, all of our faculty are asked to teach with that in mind, even in disciplinary courses, and to make the links between and among disciplines an explicit part of their courses.

My own background as an environmental historian has led me to use history as the thread that links science and sustainability in my classes. Across a range of courses I teach, asking "how was this done in the past and what can we learn from that history?" has become my primary means of pushing students to think outside the disciplinary or topical lens. For example, when looking at issues related to natural resource management in the US National Parks, we start with Stephen Pyne's book How The Canyon Became Grand, which is as much a history of 19th c. American geological

sciences as it is of the canyon itself. When exploring the impact of residential water use on local aquifers and rivers, I start with readings on the history of American indoor plumbing systems. And when talking about landscape design we read Aldo Leopold.

My basic goal is to help students realize that the problems we face today all have historical precedents from which we can learn. Geothermal heating and convective cooling have been used for centuries. So have passive solar design, green roofs, local materials, etc. A course on green building would then start with historical background not only on the aesthetics of architecture and design, but on the technical aspects of building systems that most attract students today (HVAC, energy, insulation, solar design, etc.). By exploring historical examples and examining change over time we can better understand how things came to be the way they are—to interrogate the assumptions we make about what a house should look like, how large it must be, what is "comfortable" indoors, how to heat/cool, where to get water, what to do with sewage, how it sits on the land, etc. Simply looking at data on the average square footage of new home construction across the 20th century can be quite informative; even better is to learn about the first William Levitt and Sons development in Long Island and how their decision to build in a potato field—rather than in the city –radically changed our expectations of what "home" should look like.

Historical context exists for every aspect of sustainability. The ecological is easy; we have everything from climate records to FEMA maps to tell us about how the land around us changed over time. Economic data similarly exists for almost every level of society, at least through the 20th century. Social information can be harder to come by but then qualitative data (memoirs, interviews, popular culture, etc.) can open doors that lead to questions that might otherwise go unasked.

Mari Titcombe Lee, Environmental Program, Colorado College

The Waldo Canyon wildfire: A case study of the western urban-wilderness interface

I feel the need to premise my essay with an acknowledgement - I am a novice when it comes to teaching sustainability in a formal educational setting. My background is in chemistry, a field with generally well-defined curricula for undergraduate education. The topic of "green chemistry" pops up a few times during a typical course, but is more often relegated to a separate, elective course in environmental chemistry. I now find myself in an interdisciplinary environmental science and policy program, and am only beginning to formulate my approach to teaching sustainability.

For me, the term sustainability evokes concepts of integrity and intergenerational equality in resource utilization. Definitions of sustainability are often human-centered and vary significantly between academic disciplines. But to be truly sustainable, the definition must recognize the intrinsic value of intact, natural ecosystems. To successfully teach sustainability I believe it must strike a personal chord with students. I plan to approach the concept of sustainability in the classroom by highlighting examples from the local community.

A powerful and personal example is the recent Waldo Canyon fire here in Colorado Springs. Colorado Springs is the second largest urban center in the state, behind Denver. El Paso County, encompassing Colorado Springs, has experienced a growth rate of nearly 16% over the past decade (2010 Census data). This growth has pushed residential development ever higher into previously unpopulated, forested areas and significantly increased eastern-slope demand for water (which falls largely on the western slopes of the Colorado Rockies).

Initially the Waldo Canyon fire seemed to be progressing in a controlled manor. On the morning of Tuesday, June 26th the burn area covered 5000 acres and had been kept from burning any man-made structures. There were many in the college community that viewed the fire, if not overtly favorably, at least as natural and beneficial to the health of the forest. Then Tuesday afternoon a dry thunderstorm, a typical front-range summer weather event, rolled in from the west, gusting winds up to 65 miles per hour. Flames jumped over the western ridge and into residential neighborhoods.

The city became enveloped in dense brown smoke, visibility was reduced to a few feet, and quarter-sized ash rained down. Traffic slowed to a stand-still as rush hour traffic and panic confounded residents attempts to get up to their homes, to grab loved ones, pets and important items. By Wednesday morning the fire had grown by over 10,000 acres, encompassing 18,000 acres, with 346 homes completely destroyed. The flames stopped a mere 6 miles of campus, providing a poignant visual reminder of our vulnerability to the forces of nature.

The Waldo Canyon fire is now the most destructive fire in the state's recorded history, surpassing the High Park fire, which also raged in the month of June, west of Fort Collins, Colorado. The ranking itself illustrates our bias towards (over) valuing human habitation and devaluing natural ecosystems – the Waldo Canyon fire burned 346 homes and 19,000 acres, whereas the High Park fire burned only 259 homes but nearly 90,000 acres of forest. As the town recovers from this tragedy the community, including Colorado College students, have a unique opportunity to reexamine forest management policies, development at the (sub)urban-wilderness interface, our valuation of the natural environment, and the stresses created by a changing regional climate.

Tim Lutz, Geology & Astronomy, West Chester University of Pennsylvania

The Sustainability Challenge in the Classroom

"...to suggest the possibility and the importance of the restoration of disturbed harmonies..."
George Perkins Marsh, Man and Nature (1865)

"Sustainability is the possibility that human and other life will flourish on the planet forever." Our current unsustainable existence is a result of a lost sense of connection in three critical realms: 1) our relationship to the natural world; 2) our sense of what it is to be human; and 3) our sense of responsibility to others."
Adapted from John Ehrenfeld's Sustainability by Design (2008)

"The decisions Americans make about sustainable development are not technical decisions about peripheral matters, and they are not simply decisions about the environment. They are decisions about who we are, what we value, what kind of world we want to live in, and how we want to be remembered."
John Dernbach quoted in Tom Freidman's Hot, Flat and Crowded 2.0 (2009)

"I'm always struck by how successful we have been at hitting the bulls-eye of the wrong target. We've become a culture of technicians. We're all into the 'how' of it, and nobody's stepping back and saying 'But, why?'"
Joel Salatin, Food, Inc. (2009)

Sustainability is more than developing renewable energy technologies, finding ways to store our excess CO2, or even holistically integrating the environmental sciences. I adopt the view of Ehrenfeld and others that the BIG challenge of being sustainable is attuning our individual lives and human systems anew to nature and to the essential requirements of flourishing. It means paying attention to the connections, natural and human, that run through each of us. How do we bring this to our classroom?

Sustainability is all about sensing connections; the organization of learning into disciplines is all about parceling life out into many non-overlapping pieces. Interdisciplinarity, in the sense that this still involves disciplines, is not enough. I don't accept the concept behind "integrating discipline Y into" or "adding discipline Y focus": it implies that unsustainability, which originates from reducing life to fragments, can be fruitfully repaired by gluing a few pieces back together. Rather, when you see sustainability as understanding life's interconnections as completely and responsibly as possible, then you can't help but see the threads of every discipline running through everything. If you take as a worthy subject for an introductory course on sustainability the topic "How I got my lunch today, and what might be a better way to do that," then water, soils, climate, energy, carbon, earth history, and more topics from the contents of an intro geology book

come into play. Substitute any other "X" for "lunch" in the above and you might come up with a somewhat different set but you won't miss geoscience.

I try to make disciplines disappear in my classroom. Nevertheless, interdisciplinary courses as defined by a university are a useful proving ground and possible platform for a sustainable pedagogy. Especially at the introductory level they give us the freedom to explore broad issues and connections. One of the fallacies of disciplinarity from a sustainability perspective is that each of us get to be (have to be!) an authority in something, and this tends to inhibit our movement into interdisciplinary, or better, non-disciplinary teaching. We should to set aside the idea that "adding another discipline" to our course means becoming an authority on yet more stuff.

Training, interests, abilities, colleagues and so forth all influence our perspective on what we need to know and what we are prepared to bring to a classroom. When I started teaching my sustainability course 18 years ago I didn't know much outside of geology. Teaching the course broadened my vision to the importance of history, ecology, economics, philosophy, communication, literature, pedagogy, design, psychology, management, and government. I don't "teach" these to my students per se—and yet without touching on them, how could we pursue a topic such as "How I got my lunch today, and what might be a better way to do that?"

My objective in the classroom is to be as much as possible the guide on the side, not the sage on the stage, and to facilitate this students sit around tables in discussion groups, and I circulate. I lecture and use slides as little as possible and avoid traditional textbooks. Experience and reflection, as a class and as individuals, are key. Outdoor activities and in-class readings and films (e.g., Food, Inc., Energy and Morality, Kilowatt Ours) provide a common experiential basis for everyone in the class. My students and I gather information about our own connections (e.g., consumer patterns, water and food footprints) that I aggregate for class consideration and discussion. This approach reduces my role as the authority and aims to achieve the state described by M. Perry Chapman in American Places (2006): "Active forms of learning engagement, collaborative and individual, blur the boundaries of responsibility and activity that previously separated teachers and learners. All parties are teaching and learning all of the time."

Trying to make the disciplines, the textbooks, and the professorial authority disappear leads some to ask, "Should this be a university course?" It's a good question. I believe that our universities and their curricula developed over time to serve important human needs. An unforeseen and unintended outcome of their success has been that people have forgotten to ask Dernbach's questions: who are we, what do we value, what kind of world do we want to live in, and how do we want to be remembered? We've become so wrapped up in the technology that we no longer stop to consider which target we're aiming at. How else can we explain the crisis our hydrosphere, atmosphere, ecosphere, and anthroposphere are in? Now we need to find a new direction, and we need to start changing our universities' course, big ships though they are.

Julie Maxson, Natural Sciences, Metropolitan State University

Sustainability: Teaching for a Moving Target

"You ever wonder what global warming is going to look like? In its early stages, exactly like this."
Bill McKibben on the recent Colorado wildfires*

The Cannon River, that picturesque flow through downtown Northfield MN, flooded last month. The effects were most intense downstream in Cannon Falls where the tributary Little Cannon River drops over a 40-foot height of limestone just above their confluence. For me and my neighbors, flooding means a sharp rise in the level of Lake Byllesby, a 1500-acre impoundment on the Cannon. For us, for the most part, the only disaster borne of the floodwaters is to our docks, our narrow strip of beach, and the landscaping between lawn and normal summer water levels.

This is the second big event here in as many years. And weirdly, neither flood has been in the spring, when the reservoir is drawn down to accommodate the extra water. Neighbors, at least the ones who know what I do professionally, want to know if this is evidence of climate change. To them, I have been quoting Bill McKibben a lot.

Students in my Environmental Geology class also ask, of this summer's hot, dry weather punctuated by intense storms, whether we are re-visiting some kind of Dustbowl event (about which they have just learned). To them, I also quote Bill McKibben, and further present them with data from a recent report on the increase in extreme weather events in the Midwest.** Then I pose questions back to them: Are we in an "event," or are we entering a "New Normal"? And if so, what does that mean for the systems we have been learning about – particularly in light of the evidence that our current agricultural systems may be end-dated by problems of land-loss, and soil erosion. What happens to even the hardiest, high-yielding GMO crops, and the soils that support them, if we have more dry weather punctuated by more intense storms? What are we going to do?

I learned that last question from a student. I have been teaching Environmental Science and Environmental Geology, with a heavy dose of climate science, for the past 20 years. In the first few of those years, I never thought much beyond asking students to work with the facts, to convince any doubting students that the science of environmental change was already well-established. At the end of one of those courses (which those days involved learner-engaging tasks but relatively little open discussion) one of my students asked plaintively, nearly in tears "But what are we going to do?"

I was completely kerflummoxed. And then a little embarrassed, as I realized that I had never given any though to teaching about environmental solutions. After all, solutions are so technological, or so sociological, or economical, or maybe they're just too speculative but in any case they aren't really science, right?

I have come a long way since then. I am less and less interested in teaching upper-division courses in the discipline of my training (Sedimentary Geology) and more interested in engaging students in the science, policy, culture, and economics surrounding environmental problems, working with them to speculate about solutions. In other words, I am teaching as often as I can about Sustainability.

But I am doing so in a tricky environment. I know that several of my colleagues in our small Natural Sciences department can't quite handle the word "Environmental" in course titles. They immediately associate this word with the lowest possible forms of scientific inquiry, sullied by issues of economics, policy and culture. But while thought of "Environmental Science" makes them squeamish, the term "Sustainability" makes them see red.

So what am I going to do? I have begun to engage colleagues from other disciplines, to talk about developing course and programs around an environmentally-focused, interdisciplinary curriculum that spans not just our College of Arts and Sciences, but also the Business, Nursing, and Community Development programs. Sustainability in our curriculum stands a better shot of being Sustainability Across the Curriculum at my institution, and I think that's exactly where it belongs. As my colleagues in the sciences focus on rigorously defined disciplines, I am looking beyond my discipline to find a springboard for a curriculum focused on environmental solutions.

Ultimately, our thinking about Sustainability needs to involve thinking about complex, multifaceted solutions. And it needs to involve thinking about moving targets. For this geologist, trained in extracting elements of earth's deep past, it needs to involve thinking about earth's impendent future.

*While Colorado Burns, Washington Fiddles; The Guardian, Friday 29 June 2012

**Doubled Trouble: More Midwestern Extreme Storms, May 2012. Saunders, S, Findlay, D, Easley, T, and Spencer, Theo. Rocky Mountain Climate Organization and The National Resources Defense Council. Available as a pdf at http://www.rockymountainclimate.org/reports_3.htm

Chris McIntosh, Economics, University of Minnesota-Duluth

Market Based Economies and Sustainability

Sustainability must be taught in an interdisciplinary context due to the three major perspectives it encompasses: environmental, financial, and social. I like to take a broad approach to sustainability; what are the major threats to the sustainability of a market based economy? I work through a list of problems that can disrupt a market from its economically ideal outcome and apply it to the sustainability of health, education, food, environment, etc. Notice these topics are relevant to the quality, availability, or cost of resources firms use in making products and the demand for those products. Sustainability is naturally interwoven in the economic efficiency goal of doing the best with what we have since it can influence current and future benefits and costs.

One of the great advantages of teaching environmental sustainability topics in an economic context is that there are often very simple active learning games that get at the incentives of many problems. Please see my activity submission for one such example. Two great resources for several games/activities were developed by a colleague at the University of Minnesota Duluth. Professor Curt Anderson has worked with the National Council for Economic Education for many years and published Economics and the Environment and Seas, Trees and Economies (full cites below) which detail many exercises that can be used over a broad range of levels; elementary school students through undergraduates.

There are many possibilities for enhancing the integration of geoscience and sustainability in an economic context. Much of it depends on data reliability, accessibility, and interpretation. Many sources that provide interpretations of data may be considered biased. It would greatly assist sustainability teaching to have data and government/academic studies on the most pressing issues readily available. While the importance of specific issues may be debatable, I continue by outlining interdisciplinary topics which I have a personal desire to learn more about and integrate into my classes.

· Energy resources
· Updated information on the stocks and flows of the primary US energy sources (coal, oil, and gas) available in the US and worldwide
· Pollution, accidents, and deaths from extraction through consumption of various energy resources and per energy production equivalent measures
· Latest studies about the benefits and costs of "clean coal" and "fracking"
· Physical land use limitations
· Current and future food production and the impact of meat consumption (feed lots, methane, runoff, animal feed requirement and the land needed to support that consumption, impacts of the export of the Western diet, etc.)
· Current and future (based on technological progress) limitations of cost effective wind power production on land and over water
· Potable water
· Current and future needs, limitations, and technological advances
· Progress of desalinization technologies and costs

References

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Anderson, Curt. 1999. Economics and the Environment. National Council on Economic Education. www.councilforeconed.org

Ellen Metzger, Geology and Science Education, San Jose State University

Crossing Disciplinary Borders for Sustainability Education

My relatively recent interest in teaching about sustainability was catalyzed by an unexpected opportunity to reconnect with an old friend when he came to deliver a lecture at San José State University. Randy Curren is a University of Rochester philosophy professor who, like me, grew up in New Orleans. His engagement in education for sustainability was inspired in part by Hurricane Katrina's devastating social, economic, and environmental impacts on our home town. Our conversations led to collaboration on a book about sustainability and education (in progress) which will draw on our combined expertise. This cross-disciplinary writing has prompted me to explore, for first time in my long career, the literature and methods of fields other than my own and sparked an active search for cross-department collaborations to develop sustainability-themed instruction. For example, a team of faculty from SJSU's colleges of Science, Education, and Humanities and the Arts is working on a climate change education project featuring the Green Ninja, a climate-action superhero who fights global warming by inspiring informed personal action [www.greenninja.org].

My efforts to bring sustainability concepts to the classroom have taken two forms

1. development of an elective "Science, Society, and Sustainability" course for upper division undergraduate and graduate students in education and geology and
2. professional development workshops for Earth science teachers.

In both cases, Earth system science supplies a foundation for understanding how economic and social systems are constrained by Earth's biophysical limits.

These initiatives share similar content and teaching approaches including:

- A thematic framework for relating sustainability to students' lives through connections to everyone's daily needs for food, water, energy, and materials.

- Use of multiple teaching strategies including lecture/discussion, small group activities, and reading and writing assignments to engage learners in critical analysis of the social, economic, environmental and ethical challenges arising from the collision of human and natural systems.

- Investigation of biogeochemical cycles, energy and water resources, ecological footprints, food systems, climate change, life cycle analysis, and the true environmental and social costs of energy, food, and consumer goods.

Lessons learned from these initiatives will serve as the basis for design of an introductory sustainability-themed science capstone course for future elementary and middle school educators.

John Motloch, Landscape Architecture & Land Design Institute, Ball State University

Sustainability, Collaboration and Complexity Science

We are living in an exciting, unprecedented time, when the world within the mind (of an individual or culture) and the world beyond the mind (the physical-ecological -social system) are changing at an accelerating pace. Until recently in

Earth's history, these two worlds operated as one complex adaptive system, with both worlds co-adapting, and humankind surviving as many different cultures each co-adapted with its place. Through the past two centuries, rate of human-induced change has increased profoundly and has occurred without the collaboration needed to enable co-adaptation. This has produced human impacts that exceed the rate at which the complex adapting system co-adapts its huge number of interconnected entities and interactions in ways that sustain whole-system complexity. Humanity is only now beginning to understand that, as an integral part of this complex adaptive system, humankind relies totally upon this complexity and co-adaptation for our survival and sustained health and prosperity.

Through the ages, modern man learned to adapt behaviors so as to populate virtually every bioregion on Earth and then, over time, to live outside local, regional and eventually global limits. Along the way, escalating technologies empowered by scientific knowledge have increased the impact of these technologies on Earth ... to now exceed the rate of DNA-informed co-adaptation. As a result, about four decades ago Earth arrived at a change threshold. As humankind continued its failure to embrace a co-adapting worldview, and continued its failure to operate as an integral part of complex adaptive systems, the very systems upon which we ultimately rely have been pushed to their tipping point.

Humankind is now in the process of deciding whether Earth as a complex adaptive system emerges to a higher level of health and productivity, sustains its current level, or only regenerates at a lower level. What we decide, and resulting global human behaviors, will determine whether, as part of that complex adaptive system, global society operates at a higher or lower level of sustainable production, health and prosperity. Fortunately, for 50+ years the world within the mind has been adapting toward a post-modern worldview that can empower it to embrace complexity, collaboration, and co-adaptation. Science has likewise been evolving to embrace the diversity of knowledge systems, and to appreciate complexity. Together this new worldview and science can help humankind learn how to sustain diversity and to collaborate so as to re-empower Earth as a complex adaptive system.

Complexity science also has the ability to see the very things that differentiate humankind from other species as integral parts of the complex adapting system that we refer to as nature. Science can appreciate that the majority of human-impacts to complex adaptive systems occur within built-environments; and that co-adaptation of the whole of nature -- including its human-built and non-built environments -- is essential to natural system health and regeneration. Complexity science can realize that in today's human-dominated ecosystems, to be sustainable, development must be part of a healthy, complex and co-adapting system, where collaboration informs decisions that sustain the system's ability to complexify. This includes collaboration among people who have different ways of thinking: people with laboratory-based knowledge and people who make things work in the complex, messy world; people within and outside specific disciplines; people with traditional knowledge and others with science-based knowledge; academic scientists, vernacular scientists, and artists; and people focused on built environments as well as those focused on non-built environments.

Unfortunately as Earth's biocapacity decreased, global societies intensified their competition for limited resources (to the detriment of Earth and humankind), rather than embracing the deep-collaboration needed for Earth to co-adapt into a more productive system. Education that promotes the collaboration needed for diversification, co-adaptation, and sustainability is the goal of my teaching, research, and co-leadership in U.S. Department of Education (FIPSE) funded international consortia at Ball State University. It is also the mission of The Sustainable Communities Institute (non-profit 501-3C) that I co-direct that focuses on whole systems, clean technologies, whole-system solutions, and sustainable development.

Maureen Muldoon, Geology, University of Wisconsin-Oshkosh

Service as Means of Interdisciplinary Collaboration

Most of my interdisciplinary teaching on sustainability topics takes place outside the context of traditional classroom courses. Budget constraints at large public universities often preclude the option of co-teaching courses and so while I integrate sustainability concepts in to my discipline-specific courses, it is outside the classroom that I am more able to collaborate with other faculty and staff on the teaching of sustainability. Specifically this collaboration consists of event planning, faculty development programs and curricular reform.

Our campus holds two week-long sustainability events each year: the Earth Charter Community Summit in the Fall semester and Earth Week each Spring semester. The Earth Charter Summit, is more "educational" event and focuses on the four principles of the Earth Charter: 1) respect and care for the community of life, 2) ecological integrity, 3) social and economic justice, and 4) nonviolence, democracy and peace. The week features a banquet with a keynote speaker, panels, films, and brown bag seminars. Earth Week is scheduled to overlap with Earth Day and is meant to be more "hands on". There are less formal presentations and more activities such as tree and prairie plantings, river clean up, 'art from trash" projects, etc. Serving on the planning committees for both of these events for the past 5 or 6 years has broadened my view of sustainability and required me to reach out to colleagues from many academic departments as well as to non-academic staff in order to develop interesting and engaging programs each year.

Our Campus Sustainability Plan, written five years ago, addresses all of the traditional infrastructure/facilities goals but it also includes goals for the academic aspects of the university. Our "Winnebago project" is a two-day faculty college that is meant to provide training on the topic of sustainability as well as an opportunity for faculty to re-design a course to incorporate sustainability concepts. One of the more successful portions of the workshop is a lunch-time panel wherein four faculty from diverse disciplines talk about a local issue that can be examined through a "sustainability lens" and each provides their discipline-specific perspective. I have participated on panels for a variety of topics including a proposed "factory farm", the historic contamination and current cleanup of the Fox River which runs through campus and the topic of sustainable food systems. I feel that the panel approach, where each member teaches from their knowledge area but the topics are chosen to encompass a broad range of perspectives is an effective method of interdisciplinary teaching of sustainability concepts for the purpose of faculty development.

We have just completed a major revision of the general education program at UW-Oshkosh and one of the three signature questions that will be addressed across the general education curriculum is "how do people understand and create a more sustainable world?". As we start to implement this new curriculum there is a huge need for faculty development on the topic of sustainability as well as a need for effective teaching resources. The Winnebago project will serve as our model for future faculty development programs and several faculty have been meeting informally to "pool" our teaching resources and to develop a rubric to assess students' understanding of sustainability concepts. While implementing our new general education program presents many challenges, the incorporation of sustainability concepts as an "essential learning outcome" is a big success and one that is built on interdisciplinary cooperation among a core group of faculty who have collaborated outside the normal classroom setting.

Cailin Huyck Orr, School of the Environment, Washington State University - Pullman

Demonstrating why sustainability is complex

Promoting sustainability is complicated and I am not convinced that we always understand how to do it well. This makes teaching sustainability challenging, especially to first and second year students who might expect science to have the right answers to environmental problems. My approach has been to lay out the reasons achieving sustainability is so difficult and to give students some tools to begin to approach these problems. My hope is that the next generation of environmental scientists will take us closer to achieving sustainability because they understand why engineering, legal and disciplinary approaches have failed in the past and why interdisciplinary approaches may work better.

Students come into my class having finished an environmental science 101 course where they had an introduction to sustainability as one unit in a 15 week semester. Many of them have a misconception that if people would 'just' make better choices there would be no environmental problems and that people do not make 'good' choices basically because they are greedy or self interested. My challenge is to illustrate why sustainability is complex, how economics, history and legal issues impact peoples' decisions and why equity and fairness are important to sustainability. I have done this with a place-based case study approach, starting with cases students are familiar with and moving to less familiar locations.

I use water as a focus because it is universal, easy to understand why we need it, sustainability issues can be applied to any location, and it can be linked to energy and food security. It is also relatively easy to show students that they, themselves, are not making sustainable choices when it comes to water because they do not understand the implications of their actions on water resources. For example, the water in Pullman, WA where the WSU campus sits is from a sole source aquifer that is not recharging. Most students do not realize that any water use from this aquifer is essentially not sustainable. We also talk about the amount of water needed to produce a pound of beef or a pair of jeans and how this compares to the amount of water used in activities the students typically think about when considering conservation such as showering. Once we have established how hard it is to make sustainable choices, we can explore what is important to water sustainability and build from there.

It is important for students to understand there are ways to move forward, including methods for tackling difficult or 'wicked' problems, and they have the power to instigate change. I teach the basics of adaptive management and use of scenarios as possible approaches to environmental problem solving in situations where good solutions are not obvious. Adaptive management, or management designed as learning experiments, can sometimes provide information when regular science can not. Scenarios can both prepare communities for uncertain futures and also be used as a capacity building exercise for stakeholder groups that may not initially have common goals or common vision for the future. Students have been willing to be quite involved in the projects where they are asked to applying these ideas to specific problems. I hope that the ideas we discuss with water are transferred to other types of sustainability issues as the students encounter them later.

Maureen Padden, School of Geography Earth Sciences, McMaster University

Service Learning in Interdisciplinary Courses

I began to teach sustainability when I started my present position at McMaster University. Because I was moving from a different province, the first thing I tried to do was to connect with the local environmental NGO community. I joined or contacted every local environmental group I could find. I began to use these connections to develop very applied projects in my courses and some service learning opportunities. Student feedback about these projects is varied. Many students feel very motivated to excel when there are external experts who will be discussing the final student projects. I've found the calibre of service learning projects to be very high. Another positive aspect of working on "real" unsolved problems may be useful for job searches and external experts may form useful contacts. Some students write that they find the pressure of external experts is too stressful.

I presently teach environmental studies courses to earth science, environmental science and geography students. Students in my courses are approximately evenly split between social science and physical science. There are also students from other faculties, such as business, fine arts and engineering. I find it challenging to teach upper-year students with such varied backgrounds. I want to avoid teaching to the lowest common denominator when I know the fundamentals of each discipline vary. But there are many benefits to this interdisciplinary environment for the students and for myself.

Integration of different disciplines in a university course provides a potentially rich source of discussions and problem-solving. As a society, we'll need to use both social and physical science to understand so many environmental topics and

to evaluate solutions to environmental challenges. Instead of sharing a set of fundamental skills and experience, students in my upper-year courses are able to benefit from the collective expertise of their peers. From the environmental sector, we hear that there's an increasing expectation for our graduates to have an understanding of different disciplinary approaches to complex problems. There's certainly an expectation that graduates will work productively with other disciplines in their professional lives. I hope that experiences in my courses help prepare students for an integrated approach to their professional work and a willingness to participate in civic life in their communities.

Kathleen Phillips, Earth Systems, Stanford University

Interdisciplinary Environmental Science Reflection and Communication

My approach to teaching sustainability in an interdisciplinary context is to engage the students as both active learners and teachers in class. I teach reflection seminars for both seniors and MS students that focus on science communication. My students have broad interests and academic paths ranging from food security and agricultural policy to ocean conservation to renewable energy technologies, and it is my goal for every class that all students learn from the interests and expertise of their peers. To this end, I focus on small group work with report-back to the whole class and student presentations where they explain their own expertise to the class and lead class discussion.

Interdisciplinary work requires much more in-class time that a standard course, and I have found that it is very important to student learning that I incorporate time in class for the students to reflect on what they are learning, talk to each other, and ask questions. When students are working on group projects, it has proven useful to schedule weekly meeting times outside of class with each group to help them wrestle with stakeholder analysis and refine the research questions they are asking. Students can be easily daunted when facing an interdisciplinary project and often need more guidance from the outset to define the scope and direction of their work.

One of my main goals for all of my classes is for students to improve their abilities to communicate their science to a variety of audiences including policy-makers, the public, and colleagues from other disciplines. I have benefited from working with excellent TAs and requiring all students to practice any presentations to be made to the class with the TA at least once before presenting anything to the class. This requires students to make a first cut at removing any jargon or confusing topics from their presentations. Further refinement comes from peer review of presentations in class, and I have found that students give excellent guidance and advice to each other. It helps to make peer review required, and to include acting as a peer-reviewer in the participation part of the class grade.

I'm looking forward to learning new techniques and activities from other conference participants that I can incorporate into my future classes.

Laura Rademacher, Earth & Environmental Sciences, University of the Pacific

Making Connections between Geoscience and Sustainability

My approach to teaching sustainability in an interdisciplinary context has evolved out of years of teaching about the Earth and the Environment. Initially, my introductory level courses were like many others in that they covered a large survey of topics. Recently, however, these courses have converged on a common format, which instead focuses on a handful of the most relevant topics. This format allows for students to spend more time and to dig deeper into the material and interdisciplinary connections, rather than just scratching the surface. As a geologist, I ensure that each of

the topics begins with a foundation in science and geology. But, after the foundation is laid, coverage in each of the topics branches out to include economic and social connections.

Assignments in my courses that integrate sustainability and the geosciences are designed to lead students to an understanding of how their individual choices and decisions impact the Earth. These assignments consist primarily of analyses of individual behaviors and lead to comparisons both locally and globally. For example, I often employ "fingerprint" activities (water, carbon, energy, etc.) in which students are led through the calculations of how their decisions impact a particular resource. In addition, I use back of the envelope calculations as a means of building quantitative skills, but also as a launching point for discussion. These types of activities help students to think quantitatively without increasing their math anxiety, as students are not required to have any math by the time they enroll in these courses.

The biggest challenge I face is that the vast majority of students in the introductory level courses I teach that center on sustainability are not Earth or Environmental Science majors. Therefore, the connections to student's every day lives and between the environmental, economic, and society are essential for success. In general, students are receptive to these strategies, and they often comment about the great impact these courses have on their every day lives, specifically, the links between their behaviors and decisions and their broader impacts, in course evaluations

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Mary Savina, Geology, Carleton College

Sustainability and Understanding Time

When I'm talking with students in geology courses about sustainability, I don't use the word much. As one of my colleagues, Aaron Swoboda, puts it, we know what's unsustainable about our current practices, but we don't know too much about the opposite. Instead, I try to devise assignments around geoscience and sustainability that:

- Complicate students' analyses and judgments

- Help students connect their actions to consequences (personal, local, global)

- Deal with questions of efficacy of actions

- Examine the past carefully and critically

- Make the invisible visible ("Much of the damage inflicted on land is quite invisible to laymen," Aldo Leopold, Round River, cited by Dennis Anderson, Minneapolis Star Tribune, January 7 2011)

One item on this list, "examine the past carefully and critically," has been on my mind lately. I recently attended the biennial meeting of the American Quaternary Association (AMQUA) in Duluth, MN, June 20-25. The meeting, titled "From Floods to Droughts: Water, Climate Variability, and their Impacts in the Holocene," was full of ironies, all related to what we, as geoscientists in society, consider "normal" in natural systems. We arrived in Duluth just after the area received up to 10 inches of rain in less than 24 hours June 19-20. The north shore of Lake Superior is steep, bedrock is at or near the surface, and the streams were overwhelmed by water. Lake Superior turned bright red as a result of the plumes of sediment from the rivers. Estimates of damage – for public infrastructure alone – are in the neighborhood of $100 million dollars. The previous week, we had a storm in southern Minnesota that that dumped 8.83 inches on our neighboring town of Cannon Falls (8.83 inches). In September 2010, we had the flood of record in Northfield.

Climate scientists, quite rightly, do not attribute these rainfalls (or the severe and prolonged droughts in other parts of the country) directly to anthropogenic global climate change. They say that the increased frequency of extreme events is consistent with expectations for a warming planet. And that's where the talks we heard at AMQUA come in. Over and over, whether the subject was monsoon frequency in China, fires in the American west, drought in New England, the message from study of paleoclimate proxies is that the last 200 years doesn't even come close to matching abrupt fluctuations in precipitation in the earlier parts of the Holocene. So what does sustainability mean in a world of constant natural change on which human climate forcing is superposed?

This is why the emphasis in geoscience on "examining the past" ("deep time" and understanding the past, the present and the future together as a single temporal system) is so important to convey to students while we are talking with them about the more conventional dimensions of sustainability (water, energy and mineral resources; life cycles of "stuff," etc.). Sustainability isn't about saving the earth or stopping climate change, it is about (perhaps) modulating the effects of natural and artificial transitions on the world we have now - a world with many more human lives, associated societies, and ecosystems humans depend on than earlier in the Holocene. History, as well as the Club of Rome, tells us that, depending on how we understand and manage (or not) these transitions, the result can be a graceful segue or a societal end in "fire or ice" (Robert Frost) or" overshoot and collapse" (Club of Rome).

Abigail Schade, History and Environmental Studies, Davidson College

Historicizing Water and Development

As a historian, I hear historical reasoning — whether implicit or explicit — in many discussions about sustainability and development. Human historical perspectives on environmental resources include the human perception of those resources. I am particularly interested in historical perceptions of freshwater and groundwater, and how the logic of economic development is presented by expert sources. In other words, ideas do matter. The ways we shape our material world, and our place in it, are created through our perception and valuation of these resources, and how we envision their role in our society and economy. By teaching the 'long run' of environmental resource use, bringing student attention to changing human perceptions over time, and considering the time-frame of sustainability goals, students can consider some of the unknown factors in decision-making, and articulate some of their own assumptions about best practices for sustainable development.

Through teaching a course like "Critical Studies in Water and Development," I seek to engage undergraduate students with their own authentic observations and interventions in a proliferating landscape of information. The central strength of undergraduates who enroll in this course is they want to make a difference for the better. By demonstrating some ways that development practitioners, economists, non-governmental organizations, activists, governments, scientists, anthropologists, and historians have presented, understood, and challenged the "problem" of water and development, students can find their own point of view. Again, this works because students are motivated to find where the "problem" lies, and eager to find the "correct" solution. This course functions in a discussion format, and works best when participants are willing to read widely and engage constructively with each other.

The physical basis of freshwater supplies and scarcity is an important piece in this process of asking students to make critical assessments and interventions. As a historian, not a hydrologist, I have tried to learn the basics of hydrology to point students to good sources of information, or at least know how to formulate their questions in the first place. To engage in critical source analysis, students should be able to identify confusion in popular and activist publications, while many audiences remain unaware, for example, of the role of groundwater in the hydrologic cycle.

When is undergraduate geoscience competence "good enough" for the purposes of critical thinking, assessment of discourse, and debate about how we want to understand and shape our world? I continue to struggle with this question, and hope to come out of the workshop with more defined parameters.

Steven Semken, School of Earth and Space Exploration, Arizona State University

The Relevance of Place and Sense of Place to Sustainability

In response to sprawl and globalization that challenge integrity of ecosystems and diversity of cultures (i.e., environmental sustainability and cultural sustainability), *place-based education* has been invigorated as a means of "reclaiming the significance of the local in the global age" (Gruenewald & Smith, 2008, p. xiii). Place-based teaching and learning are situated in *places*, which are localities imbued with meaning by human experience (Tuan, 1977). Places populate a cultural landscape that interpenetrates the physical landscape of landforms, water, biomes, and climate. The meanings that define places are diverse, signifying interplay of environment and culture in places from prehistory to the present. As they make meaning in places, people also form emotional attachments to them. Such attachments, especially if held by large numbers of people (for example, love of parks or wilderness areas) can be strong enough to influence the fate of these places.

Sense of place is defined as the set of place meanings and place attachments held by an individual or a community; it encapsulates the human bond to place. Sense of place informs authentically place-based education, which is trans-disciplinary (organized by the meanings or attributes of a place rather than by discipline), synthetic (infusing indigenous and local knowledge, narrative, myth, art, and scientific inquiry), and consciously motivated by place attachment. Place-based approaches to formal or informal education may be beneficial in contested places where ecological quality and cultural values for different inhabitant groups (e.g., indigenous vs. historically resident vs. newly arrived) may greatly differ—in other words, places where environmental or cultural sustainability are in particular jeopardy. A focus on the local may reveal influences on sustainability known only to populations with long histories of residence.

Place-based education is a mutually beneficial transaction among people and place if it enhances the senses of place (Semken & Butler Freeman, 2008) and local knowledge of students and teachers, while also fostering care for places (Gruenewald & Smith, 2008) that promotes their ecological integrity (Leopold, 1949; Orr, 1992) and cultural sustainability (Kawagley & Barnhardt, 1999).

My colleague Betsy Brandt (a linguistic anthropologist) and I published a book chapter (Semken & Brandt, 2010) that offers greater detail on and specific examples of the relevance of place to sustainability, and the value of place-based education in promoting environmental and cultural sustainability.

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Susan Singer, Biology, Carleton College

Feeding the World - Teaching Sustainability in a Plant Biology Course

Plant Biology at Carleton is designed to introduce students to the basic concepts of plant anatomy, morphology, evolution, biochemistry, physiology, and development in the context of food and agriculture. As a course that also fulfills a requirement for our Environmental Studies major, it is an excellent setting for introducing students to sustainability issues surrounding the challenges of feeding the world. Plants are the foundation for human nutrition and plant biology adds substantially to a student's understanding of plants as nutrients as well as what it takes to grow nutritious plants. Every topic in the syllabus from cell walls and secondary compounds to nitrogen fixation can be woven into a food and agriculture theme and used as a jumping off point for exploring how we can sustainably produce enough food to nourish our rapidly expanding population.

The current course provides two longer-term projects that engage students in sustainability topics. Over the course of the term, students read both their textbook and a popular press book, A Nation of Farmers, which makes a case for returning to small-scale farms as the only way to achieve sustainability. Students write four short position papers, guided by specific prompts that require them to analyze claims in Nation of Farmers in the context of their textbook, class work, and field trips. The short papers are a means to get them thinking and writing analytically about sustainability and how their basic science learning is relevant. The second project takes place over the entire term and results in a ten-page paper on an issue related to plants as food that is truly interdisciplinary. Beginning with a class meeting with a college librarian, students are introduced to the tools that will allow them to access literature from multiple disciplines, ranging from the science to social sciences to humanities. The prepare a paper proposal and provide an annotated bibliography that I use as a venue to provide feedback on the balance of articles, scholarly nature of the works cited, and scope of the project. I meet with students throughout the term to help them further define their work and locate evidence-based references to support the case they build in the paper. Near the end of the term, we use a jigsaw structured class format so students can share their findings with each other. The critique classmates papers (some years for credit) and can collaborate with others who have overlapping interests. To support both projects, I arrange for field trips to Syngenta (an international agricultural biotechnology company), a local cereal packaging company with a strong sustainability program, our local food co-operative, and our campus Food Truth group. My goal is to expose them to many different perspectives, including the role of genetically engineered (GE) crops in feeding the world and sustaining the food supply. Bringing in an international focus has been particularly helpful in engaging students in policy issues related to food, sustainability, and GE crops.

My goal for the upcoming workshop is to collaborate with geosciences to find ways to enhance the soil science aspect of the course. This fits in well with how plants obtain nutrients from the soil, the role of nitrogen fixation and nodule formation, and enhancement of phosphorous uptake mediated by mycorrhizae in the soil, which have played a substantial role in the evolution of land plants. We also cover the role plants have played in changing the geology of the Earth. I'm excited about several recent geoscience articles that address this topic and have begun to integrate the information on how plants have changed Earth into my course. Working with geoscientists would strengthen my approach to soils in the context of a plant biology course substantially.

Noah Snyder, Earth and Environmental Sciences, Boston College

How do we teach the science of sustainability?

The workshop introduction begins with the statement: "Sustainability is emerging as a central theme for teaching about the environment, whether it be from the perspective of science, economics, or society." To me, the term "sustainability" connotes environmental stewardship and solutions to environmental problems, and includes social and economic dimensions. "Sustainability science" implies the study of the dynamics of human-environment systems. I also see sustainability in the academic context as related to the actual running of the university (carbon footprint, physical plant, etc.), and I am interested in examples of teaching materials that use the campus as a natural laboratory to study the shift toward sustainable management of institutions. In my roles a geoscience faculty member and director of the interdisciplinary Environmental Studies Program at my university, I am interested in two questions related to sustainability:
(1) How does incorporating sustainability into geoscience curricula differ from incorporating environmental studies/science into geoscience curricula (and vice versa)?

(2) In teaching sustainability science, do we run the risk shifting too far toward advocacy? Might we start teaching students answers to environmental problems as opposed to how science informs human decision-making processes?

On the first question, over the past thirty years, many geoscience departments have been at the center of building interdisciplinary environmental programs at their universities. Now the trends are either building separate sustainability studies programs or shifting the emphasis of existing programs toward sustainability. I think these trends are positive because sustainability more clearly provides a framework for truly interdisciplinary dialog (i.e., across the entire university) than does the study of the environment. However, I struggle with how to best adjust environmental science courses and curricula to incorporate sustainability. I think that geoscience-based environmental programs have tended focused on understanding environmental problems such as climate change or the fate transport of pollutants in watersheds. At the introductory level, how does incorporating sustainability concepts into these topics yield different lesson plans? One way to proceed is make sure that each topic includes a discussion of solutions. I think that historically this is something that geoscientists have not been great at doing in their classes. The trouble with this path is that we run the risk of being perceived by students as advocating a specific solution, rather than teaching how to solve problems, as I explore further in the next paragraph. Another way forward is to more explicitly bring in interdisciplinary perspectives, for example: what are the economics and politics of preventing future climate changes? This runs into the issue of making course content too sprawling. At a curricular level, I think we need a mix of survey courses that introduce students to environmental science problems (and some solutions), which is something we have done well, and issue-oriented courses that go in depth on one topic from a variety of perspectives. Both types of courses must be offered to students without lots of prerequisites to ensure interdisciplinary participation.

As to the second question, scientists always grapple with the objectivity versus advocacy, and I do not wish to delve into that issue broadly. Suffice it say that I prefer to separate my teaching about scientific concepts from my personal views on what policies should be implemented to address environmental problems. Sometimes I editorialize a bit during lectures, but I always acknowledge this shift in perspective explicitly. The coupling of human and geologic systems forms the core of most of my research and teaching, so I am comfortable in that space. For me, the challenge is in providing students with the tools to understand how human societies need to change to become sustainable (as opposed to advocating for specific solutions). I don't have a good answer to this challenge, and it is the primary reason that I want to attend this workshop.

Hitesh Soneji, Engineering and Technology, City College of San Francisco

Productive sustainability discourse through insisting on diverse perspectives

Perhaps the most important step in making a course interdisciplinary is to attract students with a variety of interests and disciplines congruent with the primary pillars and concerns of sustainability to concurrently enroll in the same section. Too often classes consist primarily of students with an identical focus or set of concerns, potentially leading to group think. For example, engineering courses often consist of students who want to build and think that technology can solve our problems. They tend to be problem solvers, not problem understanders.

Progress on the front of sustainability requires students and instructors alike to look deeper into our problems in an attempt to tease out their roots. Well entrenched disciplinary silos guide us to address views on sustainability through the lens of our expertise. It's no different with students. Encouraging peer to peer interaction via group work or online forums has been an effective way for differing perspectives (disciplinarity) to be brought to bear on the subject matter.

Supposing a work group consists of a geoscientists, an engineer, a business major, an economists, and political scientists. We can hope such a pairing will provide the fodder necessary for interdisciplinary discourse and perspectives to be involved in the group work and learning process.

Interdisciplinarity does extend beyond the diversity of the students in a class. The instructor also needs to present multiple perspectives on issues of concern. Often the differing perspectives provide conflicting results and these have to be explored head on. Brushing conflicting or difficult ideas under the rug only serves to disenfranchise students spirited and motivated to make change.

Bill Stigliani, Center for Energy & Environmental Education, University of Northern Iowa

Teaching Sustainability: Students & Professors

My approach to teaching an introductory course in sustainability is to help students envision a sustainable future they would like to bequeath to their children and grandchildren and allowing them the space to do this, as an alternative to focusing on reductive problem solving of current environmental issues. The highlight of the course is a Public Forum, in which the students present their visions for a sustainable world. Research in organizational learning by Peter Senge and others has found that developing the potential of people and organizations to create a desirable future rests on two foundations: 1) positive visions of the future; and 2) understanding the present reality through a systems-thinking perspective. I have stressed each of these aspects in my courses. My hope is that this approach will provide my students with the skills, background knowledge, and habits of mind that will help them to understand the changing world they live in and become active contributors as society seeks to achieve sustainability. Rather than seeing a future fraught with problems, I ask my students to visualize a future filled with solutions and new opportunities.

Sustainability touches upon every aspect of human interactions with the natural world. Thus teaching it requires a broad interdisciplinary perspective that circumscribes, to the extent possible, the totality of these interactions. To augment student exposure to interdisciplinarity (and cover areas where I am not well informed), I invite guest lecturers to class and show selected videos on various themes, with the criterion that the subject areas presented reflect linkages across disciplines. Another important aspect of the students' experience is an out-of-class project that enhances sustainability. I have found that the process of doing actions such as reducing energy use in their dorms or apartment houses, or starting a recycling program at their places of work, is an empowerment experience for them as they become aware of how their individual actions can directly enhance sustainability. Also, as research has shown, this experience may be the beginning of a life-long commitment to living sustainably.

Beyond courses specifically dedicated to sustainability, the ultimate challenge for higher education is to infuse sustainability throughout the curriculum so that it becomes a part of every student's learning experience. Succeeding in this goal will require faculty members to incorporate sustainability themes into their courses. To encourage this development, the University of Northern Iowa has established the UNI Faculty Leadership in Sustainability Education Program. Twenty-six faculty members participate, representing all five colleges and spanning 19 disciplines as diverse as physics, math, geography, English literature, art and theater. In academic year 2011-2012, the participants revised their syllabi for courses they are already teaching to incorporate issues of sustainability that are relevant to their disciplines (Stigliani et al., 2012). Because of Carleton's interest to integrate geoscience and sustainability, I describe here the outcome of a participating faculty member from the UNI Department of Geography. He adapted his GIS course to include multi-criteria, sustainability-based models of the environment and human systems. Areas of analysis included erosion from cropland, watershed management, and optimizing locations of toxic waste sites, bike trails and other recreational areas, and town infrastructure.

Several pedagogic methods have been successfully applied to sustainability curriculum. One is systems thinking, which was specifically developed to study complex systems, and thus is well-suited for understanding the inherently complex interactions between the biosphere and human society. Systems thinking can be an effective way to teach students to see the whole pie rather than just the slices. Another effective method is the "pedagogy of place." Sense of one's place is important because sustainability should not be taught in an abstract, generic way. Internalizing sustainability requires an understanding of ourselves and our behaviors through affiliation with the space we inhabit. The pedagogy of place is the motivation for requiring hands-on, out-of-class projects that enhance sustainability, where students connect sustainable actions at local, familiar places with sustainability on larger scales.

Three important and successful aspects of my sustainability courses have been: the out-of-class actions to enhance sustainability; giving the students space to envision a positive, sustainable future, and articulating that vision at a Public Forum; and calculation of carbon and ecological footprints, which provide yardsticks for measuring the size of their footprints and comparing them to national and global norms. In my experience students haven not responded well to long PowerPoint lectures and much prefer teacher/student interaction and the opportunity for them to express their ideas in class. Also, especially for introductory sustainability courses, the topic is so vast that it is impossible to teach everything, and often it is difficult to discern topic areas that should be included or excluded.

Finally, it has been an honor and a privilege to teach sustainability to students so they can be better prepared to face the challenges they and their children will have to confront. Learning to teach sustainability has also led me to break down my disciplinary barriers and appreciate the need for systems thinking across disciplines. Ultimately sustainability is about people, and whether we have the capacity to prosper in ways that are mutually supportive of society and nature.

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James Stone, Civil and Environmental Engineering, South Dakota School of Mines and Technology

Teaching sustainability through project based learning

My approach to teaching sustainability revolves around an interdisciplinary sustainable design senior/graduate level course I developed. This course is open to all students on my campus, which primarily consists of engineering majors. As a result, students have wide ranging backgrounds and interests, and many of the students are interested in integrating sustainability principles into their graduate research and within their engineering profession after graduation.

This class consists of three focus areas each spanning ~ 1/3 of the semester, including: water conservation and a campus rain water harvesting project; renewable energy; and life cycle assessment (LCA). Each focus area is covered using project based-learning, where group projects are completed via interdisciplinary teams. The goals of the projects are to further their understanding of sustainability and to encourage the students to effectively communicate their findings to a variety of audiences, whether to the public, policy makers, or campus colleagues.

While I initially created this course, it has since been handed off to a new faculty with a sustainability background. We will now be co-teaching this course where I will lead a 1/3 semester LCA module. Students will learn about LCA basics followed by a hand-on project where they will determine the LCA impacts of an item or process of interest. Previously my students have presented LCA projects such as iPod manufacturing and use, and a comparison between a wool and fleece sweater of similar thermal properties.

I am looking forward to learning more about sustainability pedagogical techniques and sharing my classroom LCA knowledge.

Katherine Straub, Earth and Environmental Sciences, Susquehanna University

Keeping it lively: Incorporating readings, research, films, speakers, and writing into sustainability courses

My experience teaching sustainability in an interdisciplinary geoscience-based context is based on two courses I have taught at Susquehanna: 1) Climate and Global Change, an upper-level interdisciplinary, writing intensive course for Earth and Environmental Sciences majors, and 2) Perspectives, a required seminar for first-semester students that focuses on the academic and personal transition to college and can include academic material of the instructor's choosing (I chose sustainability, which was also the University Theme the last time I taught this course). I have taught both of these courses several times, and as I refine each from one iteration to the next, I realize that the course pedagogies have begun to converge.

Four approaches common to both courses are: 1) a diverse set of readings, 2) multiple documentary films, 3) guest speakers and outside-the-classroom experiences, and 4) lots and lots of writing.

I believe that an engaging, diverse set of course readings provides a strong backbone for any course, particularly on an interdisciplinary topic like sustainability, and keeps the course discussions lively by frequently changing the subject. In Perspectives, we had a common reading that included sustainability readings on food, sports, energy, population, religion, business, ecology, and ethics. In Climate and Global Change, I assign readings of both scientific journal articles and popular literature on the science, politics, economics, law, and ethics of global warming.

For this to work, of course, students need to actually do the reading. I ask them to come to class with a quote or question from the assigned reading. During lectures/discussions we revisit the readings frequently, and students are asked to incorporate ideas from the readings into their research and reflection papers. Class participation points typically represent at least 10% of their course grade, and I do give zeroes if students don't contribute.

The documentary films and guest speakers are intended to broaden the course content beyond what I, as the instructor, and the readings, can provide. For example, students find it much more compelling and memorable to see footage of African coffee farmers than to read about their plight in a book; similarly, hearing the University Facilities Director talk about the design of a "green" building and then walk them through our coal-fired steam plant brings to life our discussions of energy use. In both courses, students are required to submit short reflective papers on the documentary films, tying in course discussions, readings, and prior films. I have found these papers enormously helpful in assessing the students' understanding of and interest in the films, and I believe it forces them to think more broadly about the interconnected nature of the course material.

In Perspectives (the first-year course), the students were also required to design and undertake a class research project (last year, they chose to investigate the installation of a small wind turbine near campus, and interviewed several University and town personnel in the process) and work three hours at our campus garden. In Climate and Global Change, I focused more on discussions and role-playing exercises, like a mock Kyoto protocol negotiation.

I require so much writing in my courses because I believe that both research-based and reflective writing are essential skills to nurture at the college level. In Climate and Global Change, most of the students' writing is research-based, drawing on published material as well as readings and course content, while the film discussions provide the reflective component. In Perspectives, the writing is a mix of "soft" research and reflection, in the form of journal entries addressing specific sustainability-related topics. Examples of topics include:

- Contact someone from your grandparents' generation and ask what changes they have witnessed in their lifetime when it comes to food;
- Look at the "breathing Earth" website (www.breathingearth.net) and describe the overall patterns in population and carbon emissions;
- Calculate your carbon footprint, or that of your family's home;
- Watch "The Story of Stuff";
- Compare a typical meal in 3 different cultures, including your own, including the foods eaten as well as calories and percent carbohydrates, fat, and protein.

Students must address these questions in the context of course readings, discussions, guest speakers, and films. Although my section of Perspectives had to do more work than other sections (or so I heard), course evaluations at the end showed that this was worthwhile: "Overall, I had to work harder than I thought in this class, which might not have been a bad thing." "Compared to other Perspectives classes, I think we actually learned/did things." "The journal entries have progressed my writing abilities." "Journal entries were challenging and cool. I'm glad I was forced to take this class. I mean that in a good way."

Tom Termes, Industrial Technology, Black Hills State University

Using Small Team Presentations to Examine Energy Production and Energy Utilization

I provide the students with the following topics (all of these questions relate to energy in the United States of America):

1. Where does our energy come from (coal, natural gas, hydroelectric and etc.)?
2. What is the source country for each of our primary energy sources (where does coal come from, petroleum, electricity etc.)?
3. Where does energy go? That is, what is the outcome, the end use, of consuming all of the coal, natural gas, hydroelectric, petroleum, and etc.?
4. At what rate is energy consumption increasing for each of our energy types?
5. At what rate is energy production increasing for each of our energy types?

Presentations:-
Initially, the topics are discussed in class. Someone in the group may have an idea about an alternative topic that they feel is of interest. In other words we are starting with five topics, but if someone wants to talk about the growth rate of electricity generated using wind energy, this topic could be added to the list, but none of these five topics should be eliminated. We appoint ten two/three person teams, assigning one of the five topics above to each of the teams. With a class of 20 students we will have two teams on topic one, two teams on topic two, and so on (5 x 2 x 2 = 20 students).

The teams are given about a week to research the topics, and each team is given the following assignment. Provide the

class with a two to three minute presentation (three minutes maximum) with a five to seven slide power point (seven slides maximum).

In class the team presentations should take about 30 minutes. No significant discussion is allowed until all presentations have been completed. When all presentations have been given the teacher starts an open discussion about the presentations. The ultimate outcome of this exercise is to have the group come to a consensus that energy consumption and utilization in the U.S is headed down a very deadly path. The discussion at the end of the presentations should be directed toward this end.

Pablo Toral, Political Science, Beloit College

Integrating sustainability in its social context

My course pushes students to integrate the knowledge, methods and skills that they develop in the natural sciences in a broader social context, by considering the methods and skills they learn in economics, political science and ethics. The natural sciences help students understand the natural world and our impact on the environment. They also inform our strategies to overcome these negative impacts. Economics helps the students calculate the costs of environmental damage on our material wellbeing, the costs of inaction, and the benefits generated by remedial actions. Political science helps the students explain the distribution of the costs and benefits of environmental degradation and whether societies have the will and/or agency to address these challenges. Finally, ethics allows the students to understand the moral underpinnings of environmental degradation and sustainability initiatives.

Global Political Ecology is one of the core courses of Beloit College's environmental studies major. It brings together students from a very wide group of majors, including biology, geology, chemistry, anthropology, economics, education, history, international relations, political science and sociology. This diversity of majors affords me the opportunity to rely on peer learning. Every student is an expert in their field and teaches the others knowledge, skills and methods. Group assignments (in particular a sustainability project that they implement through the semester) and regular in-class updates make cross-pollination possible. I facilitate the process by highlighting the contribution of each discipline to sustainability, and by pushing them to integrate them into their projects. Our campus becomes the laboratory. The challenges the students face to implement their projects successfully pushes them to reevaluate their projects constantly in light of the knowledge and skills they pull together from different disciplines.

Lori Troxel, Civil and Environmental Engineering, Vanderbilt University

Teaching Sustainability in a Study Abroad Course

As a structural engineering professor I wanted to incorporate more about sustainability in my courses. Because of limited class time, I was unable to add this component to traditional courses. When the opportunity arose to lead a study abroad course, I jumped at the opportunity to teach a course on sustainable buildings. This university program required that it be open to any student at the university, so it needed to appeal across disciplines. By working with faculty at Queen's University in Belfast the students were able to hear a European perspective on sustainability. Through seminars the students learned how the Kyoto treaty influences policy about sustainability of buildings and how the U.K. is implementing and measuring energy usage in buildings.

Northern Ireland is small so it was easy to travel to several different academic laboratories to see energy research. In order for Northern Ireland to meet the requirements of the Kyoto treaty they need to retrofit their existing housing

stock. One laboratory built a full scale duplex. Two families are living in it while their energy usage is being monitored. After one year, one unit will be retrofitted from the outside and one from the inside. The homes will then be monitored for another year. From an engineering standpoint, the students were able to see that energy use needs to be measured before a full scale policy of retrofit is adopted. From a psychological standpoint, the students were able to see that one method will be much more disruptive to families than the other and this may have an impact on how easy it is to get people to retrofit.

Another laboratory we visited trained technicians on how to install energy saving devices in their homes. Engineers can design brilliant energy efficient equipment, but if no one knows how to install it properly, then it will be of no use. The business and construction side of improving building energy efficiency was shown to the students.

We visited a laboratory that developed and installed the first tidal generator to provide electricity to the grid. Students learned about the many regulatory actions that had to be met before this generator could be installed. The laboratory had a large wave pool for research on wave power generators. Algae biomass and algae biofuels are also being studied in this lab, so biology was also brought in to the interdisciplinary research.

Students learn an enormous amount by visiting laboratories and hearing seminars from the U.K. perspective. In order to reinforce the interdisciplinary nature of sustainability, however, students must have time for discussion moderated by the professor. Design of questions is critical.

The biggest challenges I face with the interdisciplinary class is getting non-engineers and engineers to take the same class. Non-engineers think that it will be all quantitative. Engineers think it will be too touchy-feely. I found that the non-engineers actually enjoyed learning some quantitative skills. The engineers were less likely to want to learn about policy or behavior. They tended to think that people would always choose the most energy efficient choice regardless of other circumstances.

Daniel Vaughn, Earth Science, Vincennes University

Making Sustainability Real

I have found in teaching this course (an advanced introductory course open to majors and the non-majors alike), in addition to other classes at VU and other schools, that students feel disconnected from academic information. The doom and gloom regarding the condition of the Earth and its resources are some abstraction of the evening news or Hollywood films. Classes are just a means to an end, that being the "wallpaper" that proves in their minds that they have an education. Since the environment is literally the world around them, this course is designed to serve as a connection between their existence and the environmental realities we are all painfully aware of. With an interdisciplinary background I strive to approach this from several pedagogical directions that they can absorb, accept, and relate to.

Sustainability is stressed in a number of modalities; via metaphorical measures that can be concretely conceptualized (like cubic football fields) and using quick extrapolations of observable trends (the latter being very useful for resource depletion of all sorts.) For instance we amy use a car, and break down its components roughly, and then extrapolate the amount of ores and petroleum required to make it, and then multiply by the millions of cars produced/year. In addition, regional examples are used, such as coal-mine run-off, and particulate and nutrient pollutants from agriculture (we are in a coal-mining, agricultural area.) These themes and others are encompassed in the overarching theme of humanity's temporal disconnection from Earth and its resources. That is to say, humans exist in a time span of generations which are at present around 75-80 years per. We think a generation ahead and behind our own existence with relative ease, but beyond that it starts to get increasingly abstract. We discuss this in terms of knowledge of their own families, and thoughts given to the future. Our perceptual window turns out to be astonishingly short. It is little wonder then that our

treatment of resources that exist in millenial time scales is stilted when the "real" world around us is time-wise (in our minds) so temporally small.

The issue of acceptance, and hence acknowledging some measure of responsibility, is one of the most desired outcomes of the course. I bring this notion forth repeatedly throughout, the 4th "R" (responsibility}, by having them calculate their own environmental footprints, comparing trash output, discussing "stuff" and its place in their lives, and by gauging their moral interface. This last is a simple test. On a card or paper you have two questions (with instructions clearly to NOT turn it over until instructed); 1) I can tell right from wrong: YES or NO, 2) Littering is wrong: YES or NO. On the obverse a single question, 3) I have littered: YES or NO. Using this we start what is often a profound discussion of people's morality versus environmental responsibility.

Jeff Walker, Earth Science and Geography, Vassar College

Sustainability in Geosciences in a Liberal Arts Curriculum

Sustainability for me encompasses two important concepts. It is the merging of environmental, fiscal, and social concerns to help create an equitable distribution of the world's resources. In this it assumes close attention to the local conditions within which the system of interest (institution, farm, personal lifestyle) is operating. While it is probably true that there is no such thing as true sustainability (because the systems are all open systems and we do not have control over all the inputs to the system of which we are a part) I believe that humans have a responsibility to not waste, and to use the resources at hand wisely.

Bringing these ideas into an interdisciplinary context is easy in conceptual terms, but harder in real terms because of the need to balance the practical aspects of sustainability with the academic aspects. My experiences in sustainability have been primarily practical (college sustainability coordinator for past 12 years; small-scale farmer for the past 15). In those two activities I have internalized the "three legged stool" of sustainability, and endeavored to live locally at the most basic level. The biggest challenge for me, in fact, is to think of sustainability in an academic context
There are, however, certain values associated with sustainability that I believe can be investigated through academic inquiry in important ways. The concept of waste can be studied in terms of efficiency, alternative sources, and alternative ways of doing things. Sustainability-conscious people are fond if saying that there is no such thing as "waste" but that what we call waste is just energy and materials for another ecosystem process. Besides the obvious conservation of mass/energy lessons in this statement, the idea can be used to illustrate the complexity of ecosystems, and the interconnectedness of participants (including humans) within them.

My approach to interdisciplinary teaching has been to develop topics of mutual interest to colleagues from around the college. I have team taught with faculty from Mathematics, Geography, Religion, and Political Science. In each case, our mutual interest in a topic is what led us to propose and develop the courses we eventually taught. In some cases the field aspect of the course, and the potential field experiences we could give to our students, also compelled us to teach together.

In my experience, the most effective courses have been a combination of background theory with practical field exercises. I find that the students are very interested in seeing how theory transfers to the field, and how difficult it is sometimes to realize something that makes sense theoretically in a practical setting. Although I enjoy doing this in a team-teaching setting, due to budget constraints I have had to try to give students the same experience when I am the only teacher. I am sure it isn't as good as having my colleagues there to challenge and correct me, but I think it is nonetheless stimulating to the students' intellect.

Laura Webb, Geology, University of Vermont and State Agricultural College

Geosciences in Sustainability: Upstream, Downstream, and in Between

I am relatively new to teaching about sustainability and one year ago I wouldn't have predicted being on this path. The inspiration to explore this theme relates in part to my collaborative research on the tectonics of Mongolia and Papua New Guinea, efforts that have been of interest to and garnered logistical support from mining companies. Over the years I have found myself contemplating the bigger picture of these companies operating in remote, foreign countries. My first real steps down the sustainability path are tied to having been selected as a University of Vermont Sustainability Faculty Fellow for AY2011-2012. This program included several workshops over the course of the year involving faculty from a variety of disciplines across campus and has the ultimate goal of infusing sustainability themes across a spectrum of courses offered at UVM. We have explored several topics, such as defining sustainability, systems thinking and emergent behavior, social conscience, and supporting infrastructure for developing service learning courses.

I have begun to weave a sustainability them into the rather traditional geology courses that I teach, such as petrology. To date, my petrology students and I have explored the sustainability of mineral, ore and hydrocarbon resources. After grounding ourselves in the relatively firm footing of resource formation, we attempted to address questions such as: How are known and projected resources estimated? What is the geographic distribution of production and exploration? What criteria determine economic viability of production? How resource-intensive is production? What are broader issues such as geopolitical concerns, environmental concerns, or issues related to equity (interspecies, interhuman, intergenerational)? Can innovations in technology improve economic viability or mitigate environmental concerns? Can human appetite or need for this resource be reduced?

I once struggled with ideas of how to integrate sustainability in my courses, but now see virtually endless opportunities for integrating geosciences into sustainability teaching. For example, geoscience themes dominate the upstream and downstream endpoints of technology. One only needs to ask students to pull out their cell phone and proceed to discuss where all the raw materials used to manufacturer them come from, including the petroleum-based plastics. What happens to our e-waste when you want to upgrade that phone or replace the battery? How do these upstream and downstream sides of technology affect our environment and influence political agenda? It is very easy to bring in the geopolitical and social conscience themes into these discussions. Depending on the class, these same themes can be explored and be heavy or light on the geoscience as needed.

Since having embarked on teaching sustainability, I am now thinking about courses (including collaboratively taught courses) I might like to offer in the future aimed at a broader audience than just geology majors. I found that participating in the UVM Sustainability Faculty Fellows program has been wonderful for making connections across campus and brainstorming ideas. Likewise, I believe this workshop will be a great way to broaden my perspective, networking and develop partnerships that will promote the goals the InTeGrate project.

Katryn Wiese, Earth Sciences, City College of San Francisco

Sustainability in an Oceanography Course

Currently the primary classes in which I teach about Sustainability are Oceanography, Environmental Geology, and Physical Geology. Oceanography is my primary class, and it is the perfect example of interdisciplinary, as it covers physics, biology, geology, chemistry, engineering, energy, ecology, and human impacts. Because of my audience (mostly students who will take no other science class than mine), I find an interdisciplinary nature to the class to be essential to ensuring students' one foray into science teaches them about a wide range of scientific concepts. Although I have a few majors and work to ensure they are successful as they move forward in their education, most of my students will use concepts from my class to help make better personal and political and lifestyle choices. Hence, embedding sustainability

into my class is essential.

Strategies:
- Relevant reading/lecture case studies from the local environment, such as San Francisco Bay, Sewage Treatment centers, Runoff (storm drains), and Pacific Coastal surf
- Labs and activities that incorporate data from local environmental issues, such as San Francisco Bay baseline chemistry – salinity, temperature, etc. – overlain by introduced species and ecological effects as well as the 1849 Gold Rush mercury-contamination legacy.
- Special homework assignments that give students an opportunity to take specific topics further in directed research projects (ocean pollution or a particular fishing industry)
- Basic science concepts – applying each to a relevant part of their life (to help them think for themselves)

Pedagogic approaches:
- Labs
- Homework assignments: quantitative, reading, and research projects
- Field trips
- Group work in which they share ideas and experiences while solving problems together
- In-class iClicker responses, including affective domain and gathering data on lifestyles (students can see what each other is thinking)

Successes: (the items below seem to be the most effective ways my students engage with the material)
- Group work
- iClickers
- Self-directed research

Challenges:
- Time – can't cover everything I want! I teach only one course to these students. I have to pick a few things and leave others to other courses.
- Ensuring that sustainability concern and commitment is self developed (they buy into it)
- Getting beyond initial discouragement and directing students to see what they can do to be a part of the solution

Future plans:
- Book reports on specific books/chapters (Limits to Growth – The 30-Year Update, Meadows, Meadows, and Randers)
- Discuss population issues at the beginning of the course

Ideas for integrating geoscience and sustainability:
- Working closely with faculty in other programs (ecology, engineering, etc.) to create some shared activities/exercises
- Bringing sustainability into all my classes more fully