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Sustainability Matters for Undergraduate Teaching and Learning

Catherine L. Fry
American Society for Pharmacology and Experimental Therapeutics

Cynthia A. Wei
National Socio-Environmental Synthesis Center

A growing body of evidence shows that infusing sustainability into undergraduate courses and programs can simultaneously benefit institutional goals, student learning outcomes, and society at large. In addition to being a globally relevant and urgent topic, sustainability can enhance learning of disciplinary concepts and development of broad 21st-century competencies. The authors examine the rationale for infusing sustainability into undergraduate teaching and learning and conclude by offering examples and resources for doing so.

Students at the University of New Haven are participating in a campus-wide common course on "Sustainability and Ideas for the Future." This course, the first of its kind at the university, provides a shared experience where students wrestle with some of society's most pressing challenges. The course is taught via clusters focused on interdisciplinary topics such as the future of food, energy, or the American city (see http://www.newhaven.edu/news-events/news-releases/601334/). At Emory University, a two-semester course on water draws connections between water use and availability, global health, physics, literature, art, architecture, and other seemingly disparate topics (Eisen, Hall, Lee, & Zupko, 2009).

These courses reflect a growing national trend to engage students in the exploration of "big questions"[1] and urgent societal challenges as part of their undergraduate coursework. This trend is also reflected in the rapid

expansion of sustainability programs across the U.S.: As of 2012, almost a quarter (21%) of four-year U.S. colleges and universities offer sustainability academic programs, including minors and certificate programs (Vincent, Bunn, & Stevens, 2013).

This trend is not surprising given that sustainability is a timely and urgent topic that is globally relevant. We now live on a planet that has been and continues to be profoundly changed by humans, and there is great urgency to find solutions to the complex environmental and societal problems we face. As articulated by Lubchenco (1998),

> During the last few decades, humans have emerged as a new force of nature. We are modifying physical, chemical, and biological systems in new ways, at faster rates, and over larger spatial scales than ever recorded on Earth. Humans have unwittingly embarked upon a grand experiment with our planet. The outcome of this experiment is unknown, but has profound implications for all of life on Earth. (p. 492)

This statement has been borne out in recent events, including the discovery that carbon dioxide levels on Earth recently reached the highest point in 3 million years, a milestone with as yet unknown consequences (http://www.esrl.noaa.gov/gmd/ccgg/trends/). While solutions to our global sustainability challenges will require the coordinated efforts of many sectors, higher education has a critical role to play by preparing students to solve complex problems, and by making more deliberate connections between educational institutions and local communities (for example, Advisory Committee for Environmental Research and Education, 2009; Cortese, 2003; International Alliance of Leading Education Institutes, 2009). In recognition of this role, the United Nations Educational, Scientific, and Cultural Organization (UNESCO) has called for the principles, values and practices of sustainability to be integrated into teaching and learning through its "Decade of Education for Sustainable Development" (see http://www.unesco.org/new/en/education/themes/leading-the-international-agenda/education-for-sustainable-development/).

While sustainability in and of itself is a compelling topic, and one that many students and educators care deeply about, the benefits of teaching about sustainability reach far beyond the topic itself. As exemplified by the common course at the University of New Haven, these concepts need not be constrained to specialized seminars, certificate programs, or upper-level offerings. The "big questions" of sustainability can also be an effective context through which to teach fundamental disciplinary-based concepts as well as 21st-century skills and learning outcomes, such as those defined by the Association of American Colleges & Universities'

"Essential Learning Outcomes" (Association of American Colleges & Universities, 2007) and the National Research Council (Pellegrino & Hilton 2012). We do not claim that sustainability is the only "big question" that can provide such a context. However, sustainability is an exemplar in that it can simultaneously benefit institutional goals, student learning outcomes, and society at large:

> For sustainability will be best understood within the larger framework of values, meaning, and purpose—just as "solutions" are best considered within the context of the global society. That is why the wisdom that the traditional liberal arts provide is such a vital part of any such new curriculum. Such a new approach to liberal arts, science, and sustainability will demand much of its students; it will demand even more of faculty members. But it will have one distinct potential benefit: If it is taught as an exercise in exploration and discovery, it may form the basis for a new kind of global map—a policy blueprint—that would allow us to set a common course for all the people of our rare, beautiful, and benevolent planet. (Rhodes, 2006, p. B24)

In addition, there is a growing body of evidence supporting the advantages of infusing sustainability broadly throughout the undergraduate curriculum. In this article, we examine the rationale for infusing sustainability into undergraduate teaching and learning and conclude by offering examples and resources for doing so.

Sustainability Connects Institutional Goals and Curricula

Concern about the state of the planet and its inhabitants and the potential for higher education to contribute to solutions is often highlighted in institutional goals. However, despite language within institutional mission statements about preparing students to help create a better society, this ideal is often not fully implemented (Rowe, 2007). As we will explore further in subsequent sections, integrating sustainability topics into undergraduate coursework can contribute to a variety of commonly cited institutional goals, including providing cohesiveness across the liberal arts curriculum (Rhodes, 2006; Sherman, 2008), better engaging underrepresented minorities (Basu & Barton, 2007; Bouillion & Gomez, 2001; Hill, Corbett, & St. Rose, 2010; Kuh, 2008; Lindahl et al., 2011), improving student retention and encouraging learner-centered practices (Olsen, Bekken, McConnell, & Walter, 2011), and fostering interdisciplinary collaborations among faculty (Barlett & Rappaport, 2009). Sherman (2008) makes the case for sustainability as a "big idea": a broad, interdisciplinary

topic that complements and connects the overarching lines of inquiry of the traditional disciplines. Sustainability has the potential to transform the way we think and to link common ideas across the curriculum by serving as a linchpin to make meaningful connections in diverse contexts (Sherman, 2008). Similarly, in his article "Sustainability: The Ultimate Liberal Art," Rhodes (2006) argues that using sustainability to broadly anchor the curriculum will improve its coherence and immediacy. For example, when Virginia Tech University adopted a general education curriculum centered around sustainability, faculty members found that this encouraged a more interdisciplinary approach that reduced the fragmentation of the traditional curriculum (Olsen et al., 2011).

Sustainability Engages Students and Provides a Motivating Context for Learning

Another compelling reason to teach sustainability topics is that they engage and motivate students, a fundamental goal of both educators and institutions. Students care about sustainability: concern for the state of the planet and associated interest in environmental and social issues is one of the driving forces behind the recent proliferation of sustainability-related courses and programs. In 2009, student interest was identified as a contributing factor in the creation of more than 100 majors, minors or certificates in energy and sustainability-focused programs, up from just three in 2005 (see http://usatoday30.usatoday.com/money/industries/environment/2009-12-27-green-colleges_N.htm?loc=interstitialskip). Among 9,650 college applicants Princeton Review surveyed in 2014-15 for its "College Hopes & Worries Survey," 60% said having information about a college's commitment to the environment would impact their decision to apply to or attend a school. This commitment specifically included the availability of related curricular offerings (survey results available at http://www.princetonreview.com/college-hopes-worries.aspx). Students are not only looking for sustainability skills, but also believe those skills should be delivered throughout the curriculum rather than through a discrete module or course (Bone & Agombar, 2011).

By infusing sustainability throughout the curriculum, educators can capitalize on its relevance to sustain student motivation (Barron et al., 1998; Bransford, Brown, & Cocking, 2000; DeHaan, 2005; Dinan, 2002; Hmelo-Silver, 2004; Kember, Ho, & Hong, 2008). For example, student interviews suggest that relevance—established by showing how theory can be applied in practice, either through local cases, everyday applications, or current newsworthy issues—was a primary factor in increasing

motivation for learning (Kember et al., 2008). A prominent example of this approach is *Chemistry in Context* (Middlecamp et al., 2015), a textbook used to teach basic concepts in chemistry by connecting chemical principles to students' own lives. Research by Lattuca, Voight, and Faith (2004) also supports the idea that students are more likely to engage with content if it is situated in the context of contemporary social, environmental, and political problems to which they can relate. Making connections to local issues via place-based teaching can also contribute to a sense of relevance, and has been noted for its potential to attract women and minorities to fields in which they are underrepresented (Semken & Freeman, 2008). A more recent review of 24 studies that examined the use of real-world issues as a basis for instruction found strong evidence that these issues are interesting to students and that they provide a motivating context for learning (Sadler, 2009).

Sustainability Can Improve Student Learning Outcomes

Achieving the curricular transformation envisioned by Rhodes (2006), Sherman (2008) and others will require more than specialized courses on sustainability or sustainability-focused certificate programs. It will require integrating the concepts of sustainability broadly into the existing curriculum, including large-enrollment introductory courses. These concepts should not be viewed as additions to already crowded syllabi or replacements for existing content, but rather as a context through which to teach topics already central to a course of study. Furthermore, researchers comparing learning via real-world contexts to traditional science learning contexts indicate that real-world contexts facilitate content learning as effectively (Yager, Lim, & Yager, 2006) or more effectively than traditional learning environments (Zohar & Nemet, 2002).

The complex, interdisciplinary nature of sustainability that makes it an exemplar of a "big idea" also makes it ideally suited to be taught via evidence-based practices (for instance, DeHaan, 2005; Kuh, 2008) advocated by national reports calling for improved undergraduate instruction, particularly in the STEM (science, technology, engineering, and mathematics) disciplines (American Association for the Advancement of Science, 2011; National Research Council, 2011; President's Council of Advisors on Science and Technology, 2012). Such practices focus on student-centered learning, which is typically cooperative, collaborative, and inquiry-driven (Bransford et al. 2000; Labov, Singer, George, Schweingruber, & Hilton, 2009), and includes service learning, cooperative learning, writing across the curriculum, case-based learning, problem-based learning, and oth-

ers. Supporting the idea that sustainability lends itself to these effective teaching approaches, researchers at the University of Plymouth found that the pedagogies most appropriate for embedding sustainability in their curriculum were more student-centered and interactive than traditional lectures (Cotton & Winter, 2010). Sustainability, as a pressing societal challenge, can serve as a rich context for case-based and problem-based instruction, which has been shown to improve knowledge retention (Aaron et al., 1998; Dochy, Segers, Van den Bossche, & Gijbels, 2003), students' ability to make objective versus subjective judgments (Dinan 2002), higher order thinking skills (Dori, Tal, & Tsaushu, 2003; Hmelo-Silver, 2004), and application of knowledge (Mayo, 2002; National Research Council, 2011). Sustainability topics also lend themselves well to cooperative learning strategies (including case studies), which have been shown to provide greater learning and retention in verbal, mathematical, and physical skills (Johnson & Johnson, 1989).

Teaching with sustainability concepts encourages students to use higher order thinking skills (Anderson & Krathwohl, 2001) to evaluate, analyze and synthesize information, rather than relying on a recall of definitions or descriptions of processes. Faculty report that teaching through real-world issues like sustainability engages students in active learning and helps them gain deeper conceptual understanding, engage in critical thinking, and enhance their communications skills (Herreid, 2005; Lundeberg, 2008; Waterman & Stanley, 2004). Interdisciplinary instruction like that afforded by sustainability topics also helps students develop the capacity to understand multiple viewpoints and the ability to integrate insights from different disciplines (Repko, 2009). For example, after taking Emory University's water course, nearly all of the students felt that the course helped them think interdisciplinarily and improved their ability to make broader connections and consider multiple perspectives. Through joint discussions with faculty from different fields, writing exercises, and peer review by students from different majors, students developed a more comprehensive understanding of the issues in play (Eisen et al., 2009).

In other studies, the use of real-world issues as a context for learning was associated with improved affective outcomes and gains in content knowledge (see Table 1). Zeidler, Sadler, Simmons, and Howes (2005) found that introduction of case-based socio-scientific issues represented a pedagogical strategy that more comprehensively addressed the epistemological development of students. They concluded that a major strength of this approach lies in its power to unite the various forces contributing to the development of knowledge, including moral, ethical, and emotional factors. Sadler (2011) argues that better preparing students for the issues they will face

Table 1
Benefits Associated With Teaching via Real-World Issues

Higher-Order Cognitive Skills
• Analytical thinking (Wongsri & Nuangchalerm, 2010)
• Ability to evaluate (Zeidler et al., 2005)
• Ability to synthesize (Eisen et al., 2009)
• Ability to think interdisciplinarily/make connections across disciplines and apply knowledge (Eisen et al., 2009)
• Improved grasp of the "larger picture" (Lindahl et al., 2011)
Affective Outcomes
• Responsibility/motivation for own learning (Kember et al., 2008; Lattuca et al., 2004; Lindahl et al., 2011; Olsen et al., 2011; Sadler, 2009)
• Self-efficacy (Lindahl et al., 2011)
• Finding science personally relevant (Lindahl et al., 2011)
• Improved engagement (Lindahl et al., 2011)
• Improved attitudes toward science (Lee & Erdogan, 2007)
Content Knowledge
• Conceptual understanding (Klosterman & Sadler, 2010; Sadler 2009; Wongsri & Nuangchalerm, 2010; Yager et al., 2006)
• Epistemological development (Olsen et al., 2011; Zeidler et al., 2005)

as citizens requires a contextual basis for instruction that is rooted in those very issues. For example, a study of students participating in a three-week unit on global warming indicated that after the unit, they expressed more sophisticated understandings of both the content, including the scientific underpinnings of global warming and the greenhouse effect, and the ethical challenges associated with these issues (Klosterman & Sadler, 2010).

Infusing Sustainability Into Coursework Can Benefit Faculty

Improved student learning outcomes are a compelling reason to infuse

sustainability into the curriculum, but benefits are not restricted to the student experience. Faculty who participated in Emory University's water course also reported that they were more likely to offer multi-disciplinary perspectives when teaching other courses, and that the course "changed the way [they] think about [their] own academic vocation" (Eisen et al., 2009). In a comprehensive, longitudinal study of a general education curriculum based on sustainability at Virginia Tech, Olsen and colleagues (2011) found that faculty members who taught this curriculum gradually shifted from teacher-centered to learner-centered practices. Finally, a long-term study of two faculty development programs that supported the integration of sustainability themes into pre-existing courses revealed wide-ranging positive impacts on teaching, research, interdisciplinary collaboration, and engaged action (Barlett & Rappaport, 2009). Faculty who participated also reported an increased interest in practical solutions and problem solving around sustainability challenges. A noteworthy result is that faculty did not have to commit to a substantial overhaul of their courses in order to note positive impacts on their teaching (Barlett & Rappaport, 2009).

Employers Value Sustainability Skills

An additional practical benefit of infusing sustainability into the curriculum comes from outside the academy: Employers are increasingly interested in sustainability skills and knowledge. These may include systems thinking, adaptability, understanding the relationship between people and nature, civic engagement and sense of responsibility, and considering the ethical issues surrounding a given problem. A 2011 survey from the W. P. Carey School of Business at Arizona State University found that when making a hiring decision, 97.5% of the large-firm executives said they would value a sustainability concentration, and 65% of small-company employers and 87% of large-firm employers would consider a sustainability concentration (see https://asunews.asu.edu/20110615_business_sustainabilityjobs). Moreover, broad skills associated with sustainability are also valued, whether they are gained through specific programs or certificates or through foundational coursework. A recent employer survey conducted by the Association of American Colleges & Universities (2013), found that nearly 93% of the business and nonprofit leaders surveyed valued skills associated with sustainability and agreed that "a candidate's demonstrated capacity to think critically, communicate clearly, and solve complex problems is more important than their undergraduate major" (p. 4). Students

also appear to be aware of these trends in their potential employers' hiring preferences. Of the nearly 6,000 students surveyed for a report by Bone and Angombar (2011), over 80% believed that sustainability skills would be important to their future employer.

Discussion

We have argued that infusing sustainability into the undergraduate curriculum can benefit institutions, students, faculty, and the broader community in a variety of ways. We also want to emphasize that sustainability is not a solely technical, economic, or environmental issue. As a "big idea," sustainability connects many lines of disciplinary thought across the curriculum. For example, sustainability by nature concerns systems thinking, which is often associated with science, technology, engineering, and mathematics (STEM) fields. However, the humanities provide critical meaning and perspective through historical, analytic, and cultural examinations of the components of the system (Philippon, 2012). Culture in particular has been identified as a key driver of sustainability through heritage, creative industries, shared spaces, and social capital (United Nations Educational, Scientific, and Cultural Organization, 2012). Cultural approaches to sustainability can also lead to greater social inclusiveness, resilience, innovation, creativity and entrepreneurship, and they can influence lifestyles, consumption patterns, and values related to the environment (United Nations Educational, Scientific, and Cultural Organization, 2012). As such, we want to emphasize that the humanities (which include the arts) have a critical and complementary role to play with the natural and social sciences in achieving a sustainable future.

Any topic that connects such a broad array of disciplines comes with a variety of inherent challenges. Interdisciplinary topics typically require collaboration between faculty and departments, even if courses are not team-taught. Such collaboration can be difficult, because it requires a common vision, strong leadership, shared goals, and effective communication. Some recommendations to facilitate learning interdisciplinary topics include clearly articulating common learning goals and aligning them with course assessments as well as the institutional mission and vision (Association of American Colleges & Universities, 2011). It is also important to recognize that using sustainability as an overarching context doesn't necessarily lead to improved learning outcomes for students if it is not coupled with evidence-based pedagogy. We have highlighted a number of evidence-based teaching practices that are well suited to sustainability topics, including problem-based learning, cooperative learning,

and case studies. This should not be considered an exhaustive list, however, and attention should be paid to maintaining the core principles of a given pedagogy in order for it to be effective.

We believe that the many potential benefits of infusing sustainability broadly throughout the curriculum ultimately outweigh the challenges. In order for sustainability to achieve its transformative potential, Sherman (2008) argues that sustainability

> must transcend an association with prescribed practices and even specialized areas of study. Sustainability must become a pedagogical big idea, capable of complementing and connecting avenues of inquiry across the academic disciplines that organize and prioritize teaching and learning on campus. If sustainability is employed as a method of examining the relationship between environmental limits and the human values, decisions, and actions that shape the future, it will transform not only what we do on campus, but also how we think. (p. 188)

Such a transformation will require coordinated and sustained efforts across courses, departments, and institutions. Momentum is building on campuses all over the country (for instance, Gosselin, Parnell, Smith-Sebasto, & Vincent, 2013), and our collective knowledge of how to infuse sustainability into undergraduate teaching and learning continues to grow.

We conclude with some examples of current efforts and references to resources (see Appendix A). Actions at all levels—from individual assignments to sustainability-themed courses and minors—ultimately contribute to realizing the potential of sustainability as a "big idea."

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Footnotes

[1]The Association of American Colleges & Universities' "Liberal Education for America's Promise" defines big questions as those that are fundamental

and enduring, and that have "vexed human beings" through the ages. See http://www.aacu.org/liberaleducation/le-sp07/le_sp07_featuretwo.cfm

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Catherine L. Fry *is currently the Education Manager for the American Society for Pharmacology and Experimental Therapeutics. After completing her Ph.D. in evolutionary biology and ecology at the University of Maryland, College Park, she worked on STEM education initiatives for the National Science Foundation, the Wisconsin Center for Education Research, and the Association of American Colleges & Universities. She most recently edited a report entitled* Achieving Systemic Change: A Sourcebook for Advancing and Funding Undergraduate STEM Education. **Cynthia A. Wei** *is currently the Assistant Director of Education and Outreach at the National Socio-Environmental Synthesis Center (SESYNC) where she works to advance the teaching and learning of socio-environmental synthesis. She has worked on several national STEM education programs and initiatives related to biology education and climate change education during two Science and Technology Policy Fellowships at the National Science Foundation (NSF) and the National Academy of Sciences (NAS). Previously, she was an animal cognition researcher and earned a dual-degree Ph.D. in Zoology and Ecology, Evolutionary Biology, and Behavior from Michigan State University.*

Appendix A
Resources for Infusing Sustainability Into the Curriculum

Course-Level Approaches

Approach	*Selected Examples and Resources*
Using sustainability examples to teach a course's core concepts	Textbooks such as *Chemistry in Context* (Middlecamp et al., 2015) incorporate real-world examples and themes of "big questions" in a given discipline (e.g., learning chemical equations in the context of combustion of fossil fuels).
Using sustainability as a theme throughout the course	The University of New Haven's common course on "Sustainability and Ideas for the Future" is one such approach. Course clusters are organized around sub-themes such as the future of the American city or the future of food. Common readings link concepts across clusters, and allow broader exploration of moral, ethical, political, and cultural linkages to sustainability while drawing on faculty expertise from a wide range of disciplines from the humanities, arts, and sciences. See http://www.newhaven.edu/news-events/news-releases/601334/
Using sustainability-themed class projects	University of Oregon's Sustainable Cities Initiative is a cross-disciplinary effort that integrates research, education, service, and public outreach around issues of sustainable city design. One of its signature programs is the Sustainable City Year Program, in which the university's courses focus on assisting a city in Oregon with its sustainability goals and projects. See http://sci.uoregon.edu/scy

Including sustainability in course objectives, learning outcomes, and assessments	Brundiers & Wiek (2011) developed a framework for integrating sustainability into the curriculum and the design of research projects. They present an evaluative scheme that can be applied to design or evaluate educational programs in sustainability. The Cloud Institute for Sustainability Education offers standards and performance indicators for the knowledge, skills and attitudes that correspond with education for sustainability. See http://cloudinstitute.org/cloud-efs-standards The Ohio State University and University of Maryland, College Park have developed an assessment of sustainability knowledge. Information on the development, use, and pilot findings of the assessment are available from Horvath and colleagues (2013). The Washington Center for Improving the Quality of Undergraduate Instruction has developed a set of sustainability learning outcomes and habits of mind focused on place-based learning that helps students make global connections. See http://bioregion.evergreen.edu/docs/learningoutcomes.pdf

Appendix A (*continued*)
Resources for Infusing Sustainability Into the Curriculum

Course-Level Approaches

Approach	*Selected Examples and Resources*
Using sustainability-related case studies and classroom activities	At Carroll College, case studies about reformulated gasoline were used to help students explore questions at the intersection of science, politics, and society (Lewis, 2002). Other case studies and related resources can be found from the following sources: • The Association for the Advancement of Sustainability in Higher Education (AASHE) provides resources to advance education and research in sustainability, including through informal learning. See http://www.aashe.org/resources/education-research-resources/ • The Sustainability Improves Student Learning initiative has resources available through the Science Education Resource Center (SERC) that include a "beginner's toolbox" to assist faculty in infusing sustainability into existing courses, as well as strategies for student empowerment. See http://serc.carleton.edu/sisl/index.html • The Climate Adaption and Mitigation e-Learning collection (CAMEL) contains interdisciplinary, multi-media resources for educators interested in teaching climate change causes, consequences, solutions, and actions. See http://cleanet.org/cln/ccep/camel.html • The Climate Literacy and Energy Awareness Network (CLEAN) has made available teaching activities related to climate and energy science for middle and high school, as well as undergraduate classrooms. See http://cleanet.org/index.html

Creating minors	Vanderbilt University recently created an Environmental and Sustainability Studies minor, which integrates the humanities, social, and natural sciences. The development of this minor was part of a campus-wide sustainability project that sought to build momentum around interest in sustainability issues. See http://www.vanderbilt.edu/americanstudies/sustainability A database of sustainability minors is available from the Association for the Advancement of Sustainability in Higher Education. See http://www.aashe.org/resources/academic-programs/type/minor/
Integrating sustainability into general education requirements	A four-semester general education curriculum centered on sustainability was developed for use at a large public research institution. Subsequent studies of student outcomes found that epistemological development, beliefs about learning, and intrinsic motivation were significantly advanced in comparison with students in traditional programs (Olsen et al., 2011).
Integrating sustainability into existing programs and majors	The University of Nebraska, Lincoln integrated sustainability into their environmental studies program by making it a framework concept for the program's philosophy and core courses (Gosselin et al., 2013). Northern Arizona University integrated sustainability into existing undergraduate environmental studies and sciences programs by changing curricular requirements to focus on sustainability competencies and sustainability related concentrations (e.g. "globalization and environmental change" instead of "geology" or "chemistry") (Gosselin et al., 2013).

Appendix A (*continued*)
Resources for Infusing Sustainability Into the Curriculum

Departmental- and Institutional-Level Approaches	
Approach	*Selected Examples and Resources*
Using college-wide readings	Winona State University selects a yearly common book that becomes the focus of discussions, author visits, and community events. Recent titles have served to further the university's goal of creating of a sustainable culture, and have included *Gone Tomorrow: The Hidden Life of Garbage* (2006), *Tomatoland* (2012) and *The Blue Death* (2007). See http://www.winona.edu/commonbook/
Leveraging professional development and communities of practice	Since the 1990s, Northern Arizona University's Ponderosa Project has engaged faculty across departments who share a commitment to "greening the curriculum." They participate in an intensive workshop in which they learn more about sustainability issues and strategies for incorporating them into their coursework. Part of their training is the development of revised syllabi to include sustainability content. See http://www.greenguide.nau.edu/ponderosa.html Emory University's Piedmont Project has engaged faculty in workshops and fostered curricular innovation across disciplines since 2001. Each summer, faculty across all departments of the University take part in a program that offers multi-disciplinary brainstorming around sustainability issues, place-based and experiential learning and pedagogical exercises designed to help them develop new modules that infuse sustainability concepts into the courses they teach. See http://sustainability.emory.edu/page/1021/Piedmont-Project/ The Piedmont and Ponderosa models of faculty development have inspired the creation of similar efforts at other campuses, including the Cumberland Project at Vanderbilt University (http://cumberland.vanderbilt.edu/) and the Chesapeake Project at University of Maryland, College Park (http://sustainability.umd.edu/content/curriculum/chesapeake_project.php).