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Integration of sustainability in higher education: Three case studies of curricular implementation

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Abstract
The integration of sustainability into higher education academic programs is occurring at an accelerated pace in response to international and national imperatives to rethink the way it serves the needs of society. Three case studies from the University of Nebraska-Lincoln, Northern Arizona University, and Kean University (NJ) outlines the academic structure, program, resources, the motivation and mechanisms for curricular change, key sustainability-learning outcomes and program goals, curricular changes, and assessment strategies these institutions used to integrate sustainability into their undergraduate curriculum. These three case studies exhibit several commonalities. They emphasize systems thinking and explicitly link human behavior and ecological processes by including opportunities for students to learn about behavioral sciences, life sciences, Earth and atmospheric sciences, social sciences, mathematics, physical sciences, and information sciences. Another shared attribute is that students are involved in inquiry along with the application of knowledge to real-world problems. All three programs provide opportunities for students to explore technologies, systems of economic production, cultural systems, laws and politics, and ideas and ideologies they currently employ for living with the rest of nature. Each program also provides opportunities for students to reflect and act on viable alternatives and to ask the critical questions to acquire the necessary knowledge, skills, and professional training to make a real difference in the world. Future program assessment processes will need to develop to address the issue of how differing levels and types of sustainability integration into undergraduate programs facilitate the achievement of sustainability-learning outcome goals.

Keywords: Sustainability, Sustainability Science, Higher education, Curriculum change, Undergraduate programs, Case studies

Introduction

The integration of sustainability into higher education academic programs is occurring at an accelerated pace in response to international and national imperatives to rethink the way higher education serves the needs of society. The necessity of changing higher education combined with increasing demand from students and employers is driving the transformation of existing interdisciplinary environmental education (IEE) programs and the creation of new programs focused on sustainability science and studies education (SSSE). The 2012 census of U.S. 4-year colleges and universities by the National Council for Science and the Environment revealed a sharp increase since fall of 2008 in IEE and SSSE programs—the number of schools offering IEE and SSSE programs increased 27 %, the number of degree-granting programs/units increased 37 %, and the number of degrees offered increased 57 % (Vincent 2010, Vincent et al. 2012). The number of sustainability degree programs has increased a remarkable 985 % and are offered by 8 % of colleges and universities. Many more schools offer sustainability concentrations within a variety of disciplines and professional fields (Vincent et al. 2012).

Although there has been significant increases in the number and types of programs, the extent to which sustainability is integrated into IEE programs and covered in SSSE programs varies substantially and is influenced by a range of forces including organizational hierarchies and values, external stakeholders, faculty mindsets, workloads, and available resources. The purpose of this paper is to present three case studies from three different universities with differing institutional contexts—the University of Nebraska-Lincoln, Northern Arizona University, and Kean University (NJ)—that illustrate how sustainability is integrated into their undergraduate curricular design of IEE/SSSE programs.

The sustainability movement

The increasing importance of sustainability in undergraduate programs is the result of the sustainability movement that emerged from global forums addressing environmental and development concerns. The publication of *Our Common Future* in 1987 by the World Commission on Environment and Development catalyzed what Sherburne Abbott, the Associate Director for Environment and Energy in the Federal Office of Science and Technology Policy, called the "fifth wave" of the environmental movement—the sustainability wave—characterized by a new approach to solving complex environmental problems through solutions that integrate ecological heath, social justice, and economic security over varying temporal and spatial scales (Ginsberg et al. 2004).[1]

In 1996, the President's (Clinton) Council on Sustainable Development, opined, "…environmental education is evolving toward education for sustainability. Education for sustainability is not an add-on curriculum—that is, it is not a new core subject like math or science. Instead, it involves an understanding of how each subject relates to environmental, economic, and social issues" (The President's Council on Sustainable Development 1996, p. 73).

This new way of thinking about the environment in the context of sustainability was advanced in 1998 by Jane Lubchenco when she challenged all scientists to rethink the way science and higher education is deployed to meet the challenges of the future.

The concept of what constitutes "the environment" is changing rapidly. Urgent and unprecedented environmental and social changes challenge scientists to define a new social contract…The new and unmet needs of society include more comprehensive understanding and technologies for society to move toward a more sustainable biosphere—one which is ecologically sound, economically feasible, and socially just (Lubchenco 1998, p. 491).

The term sustainability science was introduced in 2001 to describe a new approach to research and education and an emerging field focused on understanding the interactions between nature and society (Kates et al. 2001). A decade following its inauguration as a new discipline, sustainability science is a vibrant and growing field (Clark 2008), although it is still struggling to fulfill its promise of linking knowledge to action (Wiek et al. 2012) and achieving true interdisciplinarity that contributes to the development of feasible and effective solutions (Schoolman et al. 2012).

In 2003, the National Science Foundation Advisory Committee for Environmental Research and Education (NSF AC-ERE, established in 2000) released a 10-year outlook report for the National Science Foundation titled *Complex Environmental Systems: Synthesis for Earth, Life and Society in the 21st Century* (National Science Foundation AC-ERE 2003). The report stressed the importance of developing innovative interdisciplinary environmental research and educational approaches to train scientists, policymakers, and professionals in *environmental synthesis*—the merging of approaches and data across spatial, temporal, and societal scales to address multifaceted environmental issues. Subsequent AC-ERE reports—*Complex Environmental Systems: Pathways to the Future* (National Science Foundation AC-ERE 2005) and *Transitions and Tipping Points in Complex Environmental Systems* (National Science Foundation AC-ERE 2009)—continued to underscore the urgency of the need to transform environmental higher education and research toward a "sustainability science" approach.

In response to the calls for the transformation of environmental education and research and the emergence of a new focus on sustainability and sustainability science, institutions of higher education have realigned priorities and programs, instituted new programs, and designed new structures to facilitate sustainability-oriented, interdisciplinary human-nature systems problem solving, research, and education. Concepts of sustainability continue to evolve from the initial concerns about environmental and social impacts of development through the establishment of the recognized field of sustainability science to the present, when sustainability is increasingly being integrated into a variety of academic programs and new sustainability education programs are being developed and implemented in colleges and universities around the world. Vincent and Focht (2010) revealed a consensus among higher education environmental-content program leaders that the characteristics of ideal IEE curricula are consistent with the characteristics that define sustainability education and that problem solving for sustainability is the goal

1. Sherburne Abbott identifies five waves of the environmental movement that have influenced environmental education and career paths in the United States: (1) the preservation movement 1850–1890, (2) the natural resources management movement 1890–1950, (3) the ecological movement 1950–1970, (4) the regulatory movement 1970–1990, and (5) the sustainability movement 1990–present.

for interdisciplinary environmental higher education programs. In 2008, 82 % of IEE programs included sustainability in their curriculum and a third considered sustainability to be a core guiding principle for the curriculum design; this trend is increasing with more programs explicitly including problem solving for sustainability in their mission statements and defining sustainability-learning outcome goals (Vincent and Focht 2010).

Reiter et al. (2011) indicated that a common approach to the placing of sustainability-based academic programs is to create a cross-departmental program or house the program in a traditional department that is closest to what the institution thinks is the best context for a sustainability program. However, these authors propose that the preferred arrangement is to place the program in the university structure as an independent interdisciplinary department. Sterling (2004) recognized the degree to which sustainability is integrated into higher education as a continuum based on four levels of commitment and institutional response: no response, superficial changes, systemic reform, and institutional redesign based upon sustainability principles. Huntzinger et al. (2007) applied these concepts to the integration of sustainability in undergraduate engineering education programs, considered the extent to which sustainability becomes inherent in the thought processes of students, and advocated for a learner-centered paradigm that uses sustainability to promote deep learning. Figure 1 illustrates the theorized relationship of programmatic reform and the degree of integration into students' thinking. A first-level approach represents no explicit incorporation of sustainability into curricula at a program level and a lack of institutional response at an institutional level. A second-level approach represents superficial change; "bolting-on" sustainability concepts in existing program curricula or institutional systems with a small level of institutional commitment to reform an existing program. The third level involves significant change in which sustainability becomes "built-in" to program curricula or institutional systems and a greater level of institutional commitment to large-scale renovation of existing degree programs. The fourth level of response is curricula or institutional "rebuild or redesign" based on sustainability principles in which there is substantial institutional commitment to designing and implementing new degree programs.

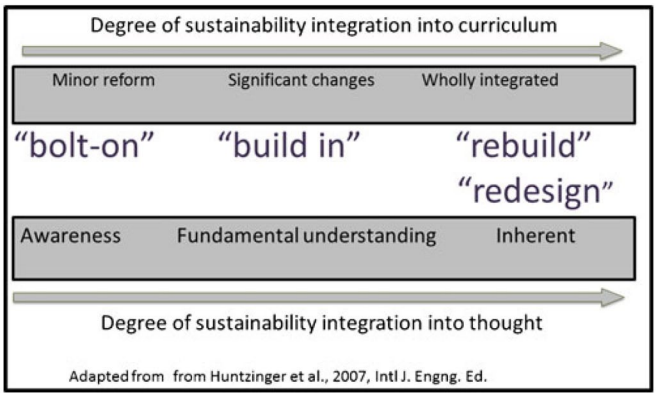

Fig. 1. Summary of models for integration of sustainability in undergraduate curriculum and student thought

In this paper, we use case studies from the University of Nebraska-Lincoln, Northern Arizona University, and Kean University to represent the different levels of institutional commitment to the integration of sustainability into their undergraduate curriculum. Each case study outlines the academic structure, program, resources, and motivation and mechanisms for curricular change, key sustainability-learning outcomes and program goals, curricular changes, and assessment strategy. By presenting the nuts and bolts of these implementations at these three institutions, others can gain a more realistic concept of the resources and commitments an institution must have to implement different levels of curricular reform related to sustainability.

University of Nebraska-Lincoln Environmental Studies Program: "bolt-on" reform

The Environmental Studies program at University of Nebraska-Lincoln (UNL), which is a Land Grant Institution and Carnegie-classified research university with very high research activity and high undergraduate enrollment, represents an example of a minor-reform ("bolt-on") type response to sustainability education in the context of the institutional system; i.e., UNL as a whole (Fig. 1). Through the process described below, the program integrated sustainability as a framework concept into the Environmental Studies program's philosophy and core courses (Table 1).

Institutional setting and perspectives for change

The undergraduate Environmental Studies program is owned and operated by two colleges, the College of Arts and Sciences (CAS) and the College of Agricultural Sciences and Natural Resources (CASNR). A part-time program director, whose academic appointment is in the School of Natural Resources, and a full-time program coordinator, who serves as the chief academic advisor as well, facilitate the program. There is no faculty FTE assigned to this program. The program currently has about 110 majors, double majors, and minors.

The Environmental Studies program embraced sustainability as a "built-in" or foundational concept that was a key driver during the curriculum updating process of the Environmental Studies core curriculum. The updating process took the core from three courses, consisting of five student credit hours, to a core of six courses with 13 credit hours. The curriculum updating process was initiated in the

Table 1. Program philosophy and learning objectives for the environmental studies program at the University of Nebraska-Lincoln.

Program philosophy: The Environmental Studies major is designed for students who want to make a difference and contribute to solving current as well as future environmental challenges on a local to global scale. Solutions to such problems as climate change, pollution, and resource conservation require individuals who have a broad-based knowledge in the natural sciences, social sciences and the humanities as well as strength in a specific discipline. UNL offers a distinct program utilizing a holistic approach and a framework of sustainability. This framework recognizes the necessity of meeting current resource needs without compromising the environment and the ability of future generations to meet their needs. The Environmental Studies major provides students with a degree and the skills necessary to work across disciplines and to be competitive in the job market. Students will acquire a broad-based education in the physical, biological, and social sciences and develop competency in a specific discipline.

Learning objectives

Students completing the environmental studies degree program will acquire knowledge of:

- L.O. 1. Earth and Ecological Systems: Understand the structure, function, and interaction among Earth's four major spheres: land, water, living things, and air in the context of the physical, geological, and biological processes as well as human influences and their variability over space and time.
- L.O. 2. Human Dimensions of Environmental Challenges: Understand how law, politics, ethics, economics, historical setting, and cultural diversity influence past, present and future public policy, decision-making, and risk assessment related to environmental challenges at local to global scales with emphasis on environmentally sustainable development.
- L.O. 3. Methods, Tools and Technology: Use and apply relevant field, laboratory, geospatial, and social science research methods, tools and technologies to address environmental challenges in an ethical manner.

Students completing the Environmental Studies degree program will have opportunities for:

- L.O. 4. Professional Development: Integrate classroom learning with practical application through internships, international study experiences, and undergraduate research experiences.
- L.O. 5. Communication: Use and apply written and oral communication skills for different audiences and purposes including oral presentations, public speaking, online publishing, and visual displays of environmental information.
- L.O. 6. Collaboration: Collaborate as members of teams, effectively working with multiple stakeholders from various backgrounds to address environmental challenges.

Students completing the Environmental Studies degree program will use (an)

- L.O. 7. Interdisciplinary Approach: Integrate multiple kinds of information, tools, and methods from a variety of disciplines to analyze and construct arguments about complex environmental challenges and sustainable development.
- L.O. 8. Critical Thinking and Problem Solving: Synthesize interdisciplinary knowledge, technical knowledge, and research methodologies to complete a capstone senior thesis project.

Fall of 2008, shortly after the appointment of a new director of Environmental Studies (Gosselin). The director and the coordinator drove the updating process and assessed the current situation regarding the extent to which the Environmental Studies curriculum could be changed and modified. Because of limited institutional commitment to sustainability as an educational concept at the time of the changes, the UNL Environmental Studies program chose to integrate sustainability at the program level where it had control of curriculum content. This process required minimal university resources and institutional commitment to add sustainability as a framework element during the modification of the existing environmental studies program. The updating process was supported by the Environmental Studies Coordinating Committee that consisted of four members of the faculty from each college and a representative from each of the respective dean's offices. The biggest challenges that were encountered during the process involved having to move curricular changes through two different colleges and associated processes. For the most part, there was little or no significant resistance encountered from faculty. The new curriculum was implemented in the Fall of 2010.

Motivation and mechanisms for curricular change

The curriculum updating process was informed by discussions with the deans of the CAS and the CASNR; feedback from alumni, students, and employers; conversations with faculty from collaborating disciplines including the ESCC; and consultation of national documents and the published literature specifically emphasizing environmental and sustainability literacy and best practices for the intellectual development of undergraduate students. As a result of the information gathering process, the following four basic principles were developed to provide the educational framework for the UNL-ES program:

1. Promote an educational environment that is consistent with calls for improved learning in higher education based on how people learn (Bransford et al. 2000; Zemsky 2009).
2. Create opportunities for students to develop twenty-first century competencies that are necessary for long-term professional success; emphasizing collaboration, critical thinking/problem solving, ethics/social responsibility, professionalism/work ethic;

creativity/innovation, and lifelong learning/self-direction (CISCO 2008; Partnership for 21st Century Skills P21 2010; National Research Council 2012)

3. Support the United Nation's vision of education (United Nations 1992, 2002); that is, "linking social, economic, political, and environmental concerns" which "demands a deeper, more ambitious way of thinking about education, one that retains a commitment to critical analysis while fostering creativity and innovation."
4. Develop a learning environment that focused on student success whereby students are not only engaged in their own learning, but engaged with the community as well (Bransford et al. 2000).

Key sustainability-learning outcomes and program goals

Table 1 lists the program philosophy and learning objectives for the program. If these overarching objectives are achieved, program graduates will be conversant in the issues and demands of global society; prepared to meet the needs of employers who want employees that possess twenty-first century competencies; and able to work across disciplines. Ultimately, they will be competitive in the job market or matriculating into graduate programs.

Sustainability is a basic framework principle embedded in the program philosophy. Although there are many different definitions and interpretations of this term, the emphasis for the UNL program is on the importance of sustaining the life-support systems of the planet while meeting the needs of people today and in the future. The program's curriculum consists of four components: core courses; collateral courses; an emphasis area, and a senior thesis or project. In this approach, the ability to address the challenge of sustainability to meet current and future resource needs without compromising the environment is fundamentally a concept that is an outgrowth of systems thinking. Systems-thinking, in its simplest form, recognizes that "everything is connected to everything else" (Commoner 1971). Inherent in the concept of sustainability is the interaction between human, economic, and environmental systems.

Curricular changes

Connections between human, economic, and environmental systems are emphasized from various perspectives in the six courses that comprise the core of the program (Table 2). Furthermore, students have multiple opportunities to practice critical thinking and problem-solving skills to develop creative solutions for complex environmental challenges including sustainability. The development of these skills along with other twenty-first century competencies plus the ability to think about systems requires the concomitant facilitation of intellectual growth and development. To accomplish this type of facilitation, pedagogical approaches, and high-impact educational practices are used that promote student independence, self-directed learning, and self-reliance.

To successfully implement sustainability practices, an understanding of the structure, function, and interaction among Earth's four major spheres or systems: land, water, living things, and air in the context of the physical, geological, and biological processes as well as human influences and their variability over space and time is required. In addition, knowledge of how law, politics, ethics, economics, historical setting, and cultural diversity have influenced past, present, and future public policy, decision-making, and risk assessment related to environmental challenges at local to global scales is needed if environmentally sustainable development is to become the norm. These educational requirements are addressed through a set of collateral courses that includes instruction in Earth systems including climate, Earth and energy resources, soil resources, and water resources; geospatial science including GIS, GPS, and remote sensing; statistics; and human dimensions including sociology, anthropology, ethics and law, resource management and leadership, economics, and policy.

Another important attribute of the program is the development of competency in a specific discipline. By the middle of their junior year, majors are strongly encouraged to complete an individual course of study plan in collaboration with the program coordinator that specifically defines an emphasis area. The emphasis area includes 18 to 24 h of instruction in one of the following disciplines: anthropology, biology, chemistry, communication studies, geography, geology, meteorology–climatology, political science, psychology, or sociology (through the College of Arts and Sciences); or applied climate science or natural resources (through the College of Agricultural Sciences and Natural Resources). Associated with each of these em-

Table 2. Summary of Environmental Studies courses (ENVR), credit hours, and learning objective

Course	Credit hours	Learning objective
ENVR 101 Environmental Studies Orientation	1	5, 6, 7
ENVR 201 Science, Systems, Sustainability and the Environment	3	1, 5, 6, 7, 8
ENVR 249 Individual and Cultural Perspectives of the Environment	3	2, 6, 7, 8
ENVR 319 Environmental Engagement in the Community	2	4, 5, 6, 7, 8
ENVR 497 Internship in Environmental Studies	1	3, 4, 8
ENVR 499 Senior Thesis	3	3,4,5,8

phasis areas are math, life sciences, and physical science (chemistry and physics) requirements.

The final piece of the puzzle of the program is the requirement that each student complete a capstone senior thesis (ENVR 499) with permission of the program director and under the guidance of a faculty adviser. Students are strongly encouraged to choose a topic about which they are passionate in order to take advantage of internal motivation and interest.

Assessment

All students entering the program participate in a one credit, one semester orientation course (ENVR 101) designed to introduce the discipline of Environmental Studies. As a class assignment, students are asked to go online and complete a pre-program assessment using the TriMetrix® DNA instrument (see explanation below). A couple of critical thinking assessment instruments have also been explored. All students completing the program (post-program) participate in a two credit, one semester senior thesis course (ENVR 499b) designed for completion of undergraduate research. As a class assignment, students are asked to go online and complete the TriMetrix® DNA, a sense of community instrument, and the alumni survey from the National Council for Science and the Environment. Participation in these assessment activities is part of the regular course; however, participation in the research component is voluntary. In addition to the program assessments, individual courses are assessed using Course/Instructor Evaluation Questionnaire CIEQ required by the CASNR. The CIEQ is a student rating form and statistical analysis package designed for use as part of a program for assessing both course and faculty teaching performance: http://www.cieq.com/

To assess the extent to which the objectives related to twenty-first century competencies are achieved, the program has partnered with Target Training International, Ltd (TTI), to gain insights into the behaviors, motivators, and personal and professional competencies of program majors to determine their growth throughout the program, as well as their individual correlation with pre-defined employer expectations. The instrument that is used to assess these personal attributes of the students is the TriMetrix® DNA, which, as the name implies, has three parts. The TriMetrix® DNA assessment tool is an online survey system that reveals the how, why, and what of individual performance. The three-part system assesses the behaviors that people bring to the job, the values that motivate people to do a job, and extent to which people have obtained personal skills. The first assessment measures normal behavior or *how* people make decisions and how they want to receive communications that influence them. The second assessment looks at their passion or the *why* behind their actions. The third assessment, measures 23 competencies. Through the self-evaluation assessment of an individual's own soft skills, this quantitative measurement tool analyzes each capacity on three levels: mastery, some mastery, and not yet mastered. The assessment results define which skills an individual has developed. By comparing students' results before and after completing the program's requirements, determining the extent to which the program has facilitated the development of twenty-first century competencies is possible.

Northern Arizona University (NAU) School of Earth Sciences and Environmental Sustainability: "build-in" reform

Northern Arizona University is a Carnegie-classified research university with high research activity and high undergraduate enrollment. The process NAU followed serves as an example of a "build in" level of curriculum reform that occurs throughout the curriculum and the institution (Fig. 1). NAU chose to renovate its existing undergraduate environmental studies and sciences programs and adapt them to provide more sustainability studies competencies, all without creating a new degree program. The institution also committed to maintaining high enrollment numbers in current majors (enrollments are over 400 in environmental studies and sciences and over 100 in geosciences).

Institutional setting and perspectives for change

The current NAU environmental and sustainability degree programs include traditional undergraduate environmental sciences and studies programs and more recent and innovative graduate programs. The 30-year old B.S. in Environmental Sciences has an eight-course core with an additional required emphasis area in geology, mathematics, biology, chemistry, administration and policy, communication, or management. The B.S. or B.A. in environmental studies was initiated 5 years ago and requires some of the same core courses, but instead of an additional disciplinary concentration requires a focus in: Globalization and Environmental Change, the Southwest, or Sustainability, Community and Diversity. More recent curriculum development resulted in graduate programs with sustainability foci (MS in Climate Science and Solutions, MA in Sustainable Communities, MS in Environmental Sciences and Policy, PhD in Earth Sciences and Environmental Sustainability). The School of Earth Sciences and Environmental Sustainability (SESES) offers these programs and has 26 full-time teaching faculty members, the majority focused on geosciences degree programs. Eleven of the school faculty members plus five affiliated faculty members from other NAU academic programs provide teaching and advising support for the 400+ majors in the undergraduate environmental studies and sciences programs.

Through the process described below, new sustainability-based learning outcomes were created (see Table 3) and programs were renovated to add sustainability education while preserving the strongest attributes of the existing programs. The faculty in the NAU School of Earth Sciences and Environmental Sustainability's environmental studies and sciences (ENV) programs were enthusiastically engaged throughout the revision process, both through internal curriculum review and revision and through participation in a university-wide global learning initiative (GLI), described below. The review and evaluation of curriculum and the GLI identified the need for more sustainability-related skills and content. The faculty was initially concerned that additional sustainability-learning outcomes might come at the expense of existing core course material. However, as new sustainability-learning outcomes were focused down to the individual course level, it became clear that they were consistent with existing course objectives and could be readily meshed with existing learning outcomes and activities. As a result of this process, the faculty members are strongly committed to moving the environmental studies program in the direction of sustainability while maintaining the existing environmental sciences degree with its more traditional emphasis on natural sciences and resource management and policy.

Although no faculty lines were reallocated to accommodate the curricular changes, substantial university resources were made available to help existing faculty rethink and add additional sustainability-learning outcomes and program goals within the context of their existing programs. One-time funds through the Provost's office were available. Two sets of funds provided stipends, one of which supported three members of the faculty to work on program-level curriculum evaluation and revision (the Student Learning and Curriculum Development program). The fund also supported three faculty members to focus specifically on developing and implementing learning outcomes in sustainability, diversity, and global engagement. By re-tasking existing courses (through revision of course-level learning outcomes), and replacing elective options with specific, sustainability-focused courses, we were able to make the curriculum changes without the need for additional new courses sections. This process occurred with widespread faculty participation through workshops and summer stipends, and with the active support of the NAU Office of Academic Assessment. Thus the NAU process is at its core resource-intensive and provides an example of the type of sustainability-learning outcomes achievable at this higher level of institutional commitment.

The curricular changes developed at Northern Arizona University occurred at a confluence of senior administration priorities and interest in curricular change by the fac-

Table 3. The process for developing and incorporating sustainability outcomes in an existing environmental curriculum at Northern Arizona University

Design stage	Activity and example
Ia. Initial discovery	Discuss, define, and accept definitions of sustainability studies concepts and competencies; relate to Global Learning Initiative document. *Examples:* define sustainability (the maintenance *and enhancement of the resilience, diversity and long-term stability of linked natural, social/cultural, and economic systems*) and sustainability-learning competencies (e.g. use natural resources in ethical and responsible ways that maintain a sustainable environment; understand the role of human interactions with the natural environment in the root causes of global issues)
Ib. Detailed discovery: existing curriculum	Catalog existing sustainability outcomes and competencies at course and program levels. *Examples*: program level: understand system structure, function, resilience, diversity and stability across local to global scales for natural and human systems; course level: understand the complexities of the science/policy interface
IIa. Program-level curriculum mapping	Determine all level learning outcomes and competencies for environmental and sustainability studies and their linkages to global engagement and diversity. *Example:* Understand how technology, economics, and culture impact environmental systems and approaches to adapting to or mitigating these impacts at multiple scales
IIb. Course-level curriculum mapping	Determine all learning outcomes and competencies for environmental and sustainability studies within each core course. *Example:* understand the relationship between environmental legislation and environmental regulation
IIc. Gap analysis, where existing curriculum is inadequate	Determine where courses do not address program outcomes and competencies; map how to build multiple levels throughout the core curriculum. *Example:* need to expand ecological systems concepts to combined cultural/environmental systems.
IIIc. Course renovation/redesign	In each course develop new activities and assessments to address gaps identified. *Example:* Refocus hydrologic systems studies on the energy–water nexus to emphasize social/cultural/economic controls on water resource sustainability

ulty in the ENV programs. The Provost and Faculty Senate identified sustainability as a central learning theme throughout the university and support sustainability education through the Global Learning Initiative. The Provost provided the funding opportunities, but they were voluntary programs. ENV program faculty chose to participate in these programs because they provided the funding to support a reexamination of environmental curricula as well as a framework to ease curricular changes through the university approval process. One-time funding came from above, but leadership and implementation came from faculty with the ENV programs.

Motivation and mechanisms for curricular change

NAU, in general, and SESES in particular, has recognized the need to move from problem-based learning centered on environmental issues to solutions-based learning including adaptation and mitigation centered on enhancing resilience, diversity, and sustainability of linked natural and social systems (our definition of sustainability). While reviewing the environmental curricula, NAU faculty looked for learning outcomes from long-term overviews like the Millennium Ecosystem Assessment (UN Millennium Project 2005) and Recommendations for a Sustainable Future (Blockstein and Greene 2003). As the field of sustainability science expanded through the 2000s, it became clear that we could not provide a brand new degree program in sustainability while maintaining existing degree programs in environmental sciences and studies.

This recognition occurred in two stages. First, an understanding that more sustainability-learning outcomes could be integrated into our existing degree programs without the need for a new degree program. During SESES participation in the campus-wide GLI described below, more learning outcomes specifically for sustainability were added to existing degrees. For example, we increased attention on the mitigation and adaptation to environmental challenges, from both natural sciences and social sciences perspectives. The second stage was a separate, voluntary, university-wide program of curriculum redesign (the Student Learning and Curriculum Design process; SLCD).

The first major driver for curriculum reform within SESES came from a campus-wide effort to infuse concepts of global engagement, diversity, and sustainability throughout each major at NAU. With its pioneering Ponderosa Project (Bartlett and Chase 2004), NAU has long practiced infusing environmental awareness throughout the curriculum. Over the past several years, NAU faculty across the university recognized that issues surrounding, and competencies dealing with environmental sustainability are inextricably tied to those of global engagement and diversity. This recognition was occurring at the same time that other faculty and administration members were attempting to infuse more global engagement and diversity learning outcomes throughout every major at NAU.

These three thematic areas: sustainability, global engagement, and diversity became three of the key strategic goals in the NAU strategic plan. As a result, a task force of over 40 NAU faculty developed a plan to introduce integrated global engagement, diversity, and sustainability-learning outcomes at multiple levels within each major program. Task force recommendations were included in the GLI Action Plan and ratified by the NAU Faculty Senate. The GLI action plan provides resources for developing course and program-level learning outcomes and for linking them to improved teaching and assessment tools with cooperation from NAU's Office of Academic Assessment. Beginning in 2010, resources for the GLI were provided through the NAU Center for International Education, which awarded small grants and summer stipends to groups of two to four faculty members from individual academic units, including SESES.

Two roles in GLI were established for academic units with expertise in sustainability. One role for SESES faculty is to serve as peer mentors to other academic units and as advisors to the GLI administrators. We suggest appropriate materials, case studies, and competencies for units looking to infuse sustainability throughout their degree programs. Workshops and one-on-one collaborations are used to provide this assistance. Some of the NAU courses are being adapted to provide some (but not all) sustainability content for other majors through their general education requirements.

Our second role, in common with other academic units participating in GLI, was to revise the curriculum to develop and to enhance learning outcomes that establish increasingly sophisticated engagement with linked global, diversity, and sustainability issues throughout undergraduate students' progression through their major. Through a three-stage process, new sustainability-learning outcomes were incorporated into the curricula of the interdisciplinary environmental degrees. In the first (discovery) phase of this process, campus conversations, conference presentations, literature reviews and site visits were used to identify appropriate competencies and learning outcomes, especially those linking the three GLI themes (Table 3). For example, the need to add principles and applications of environmental justice utilizing diverse perspectives from multiple communities was determined. In the second phase, existing curricular outcomes were compared with the newly developed criteria, which determined where to strengthen competencies and outcomes (e.g. linkages between natural and social/economic/cultural systems by having students apply an understanding of ecosystem services to regional resource management). This information was used to determine where ability outcomes such as understanding of principles of resource management and environmental policy at multiple scales were satisfactory.

Key sustainability-learning outcomes and program goals

Northern Arizona University's programs share several of the attributes with the Environmental Studies Program at UNL: a set of core courses that explore soil, water, air, and energy resources, and environmental management, law, and policy; and a required internship or research experience. With programs in both studies and sciences, majors were differentiated, with the environmental sciences program maintaining competency in a specific discipline path, as is required at UNL, but with the studies program focusing on interdisciplinary sets of courses addressing major sustainability issues and challenges.

Table 4 summarizes the key sustainability-learning objectives developed through the rebuilding process. In determining whether to create a new sustainability curriculum or to build sustainability into an existing curriculum, SESES faculty determined that the existing curricular structure of both undergraduate programs provides sufficient learning outcomes in interdisciplinary synthesis, written and oral communications, systems thinking, quantitative analysis, and information literacy. These decisions were made at the same time similar conversations about these learning outcomes were occurring in other NAU departments, in part due to the workshops sponsored by the GLI. It was agreed that these learning outcomes are critical and that they would be maintained. The initial objective was to revise specific parts of the curriculum to change the major focus from an academic focus on specific systems' structure, function, and problems (ecosphere, hydrosphere, atmosphere, etc.) toward a focus on enhancing resilience and diversity in linked natural and social system components (agricultural and biological systems, water systems, energy systems, just and sustainable social/cultural/economic systems). However, larger-scale efforts were simultaneously occurring across NAU.

New outcomes (Table 4) were established including an awareness of sense/culture of place and responsible actions affecting natural and social/cultural environments. Finally, the curriculum and assessment are now being redesigned within the context of the existing degree programs. Outcomes are being mapped through the curriculum across the entire program, for example, how to conduct interdisciplinary analysis (work with others in application of multiple disciplines to analyze complex biophysical/culture issues) and how to improve informational literacy (media searches, source discrimination, literature analysis). Through assessment in individual courses, it will be demonstrated how outcomes are developed through multiple levels of competency up the course sequence. Through an assessment system linking individual course learning outcomes between courses and to program-level outcomes, the success of the entire program and to keep the curriculum revision process adaptive to more effective approaches to these learning outcomes will be assessed.

Table 4. Pre-existing and newly developed learning outcomes for NAU ENV undergraduate programs

Pre-GLI process learning outcomes for ENV curricula

1. Enhance awareness of relationships between human and non-human components of the environment at local to global scales
2. Generate environmentally aware citizens who are inspired, committed, active, participatory, persuasive and influential
3. Understand of system structure, function, resilience and stability/sustainability across all scales from the local to the global, including biotic, abiotic, and cultural components
4. Understand the science/policy interface
5. Understand principles and applications of energy and biogeochemical cycling
6. Ability outcomes
   a. Systems modeling based upon quantitative reasoning including basic statistical analysis, error analysis
   b. Understand and explain the science behind our understanding of environmental change
   c. Demonstrate and apply an understanding of principles of resource management and environmental policy at all scales
   d. Demonstrate and apply an understanding of ecosystem services
7. Dispositional outcome: students will develop their awareness of personal place and responsibility at local through global scales and demonstrate critical reflection of self in relation to society and environmental problems

New learning outcomes developed as a result of the GLI process

1. Learn how to develop, conduct and describe the results from a significant independent project or research activity
2. Understand and apply concepts of systems analysis including resilience and resistance, stability, linkages, tipping points. Use this knowledge to understand relationships between linked environmental and cultural systems.
3. Understand the significance of biocultural diversity in the functioning of linked environmental and cultural systems.
4. Understand the differential impacts of resource extraction and pollution emissions on different populations.
5. Able to perceive and understand landscapes and ecosystems from a variety of perspectives
6. Understand roles as scientist and citizen and willingness to effectively engage in interface of environmental science and policy

Through both roles in the GLI, SESES has not only improved its connections to other academic programs throughout the university, but also significantly improved the quality of its undergraduate curriculum.

Curricular changes

The programs at NAU have not undergone major changes in their structure and composition, but individual courses have been significantly redesigned. A sequence of core courses in both the environmental studies and sciences programs has been retained, culminating in a senior capstone course where students report on their individual research or internship activities. In addition to the core course sequence, environmental science students continue to take a set of major courses in a natural or social science discipline, while environmental studies students take a structured set of interdisciplinary courses focusing on a sustainability or environmental issue (http://nau.edu/CEFNS/NatSci/SESES/Degrees-Programs/Undergraduate/). All of the renovation has occurred within the context of additional learning outcomes for the degree programs and for existing courses.

Assessment

The current assessment process for SESES and its environmental programs remains unchanged by the renovation process. As part of this process, new assessment metrics to reflect the additional learning outcomes at both the course and program levels are currently being developed.

Existing assessment tools include: developing the program-level learning outcomes discussed above, with specific objectives for each course measured with formative and summative assessments within each course; assessing cumulative student performance in the junior writing course and in the senior capstone course (by all the environmental faculty); and group exit interviews following the senior capstone course. The Haub School of Environment and Natural Resources at the University of Wyoming has undergone a similar process for curriculum redesign and assessment, is farther along in the process than SESES at NAU, and is willing to share the assessment tools it has developed (Maggie Bourque, personal communication, 2012).

Kean University Sustainability Science Program: "rebuild and redesign"

Kean University is a Carnegie-classified masters level university with high undergraduate enrollment. It is the third largest university in terms of total student population in New Jersey. Consistent with the suggestion of van Dam-Mieras, et al. (2008) that "the time for innovative sustainability education in colleges and universities in the United States is upon us" and that "all educational institutions–from preschool to higher education–can and should consider it their responsibility to deal intensively with matters of sustainable development" (p. 252), Kean University decided to take an approach that wholly integrates sustainability into an entirely new B.S degree program in Sustainability Science consisting of more than 40 new courses created specifically for the program. Kean embraced the rebuild-redesign paradigm (Fig. 1), rather than use the bolt-on or build-in models that was frequently used with the ancestor of sustainability education, namely environmental education. These models have been suggested to have failed to achieve the potential of environmental education as a progressive and innovative form of higher education (for example Saylan and Blumstein 2011; Speth 2004; Van Matre 1990). The philosophy that guided Kean was that degree programs, be they undergraduate or graduate, associated with education for sustainability needed to go beyond simple rebranding an existing curriculum perhaps with the creation of one or two new courses with sustainable and or sustainability in the name of the course, and then marketing or branding them as a new academic program. Kean undertook a deliberate and systematic effort to use sustainability as an entirely new way of teaching and learning that prepares students to be responsible denizens of Earth, regardless of where they are receiving their education.

Institutional setting and perspectives for change

The academic home of the B.S. in Sustainability Science program is the Center for Sustainability Studies (CSS), which is housed in the College of Natural, Applied and Health Sciences. The Executive Director (Smith-Sebasto) of the CSS administers the program. For the Fall 2012 semester, there were about 40 declared majors in the program, which admitted its first cohort of majors in September 2010, when there were 13 declared (26 declared at the start of the Fall 2011 semester). There are 41 courses that include the word sustainability in the course name that are included in the program.

Faculty from Biological Sciences, Chemistry and Physics, Computer Science, Geology and Meteorology, and Nursing comprised the ad hoc committee charged with developing the original B.S. in Sustainability Science degree proposal. All members of the committee supported the concept of a program in sustainability. Survey research supported student interest in such a program. The research supported the development of the program. The biggest concern of the faculty was staffing because several of the related departments were already understaffed.

To support the development of the B.S. in Sustainability Science program, the president of the university com-

mitted funding for creation of the program approval document. A new open-rank faculty line with responsibility for oversight of the program was approved. This position evolved into a managerial level position when it was initially filled. A second FTE was allocated to the program in its second year. Faculty from other administrative units on campus have taught courses in the program as affiliated faculty in the Center for Sustainability Studies, but no FTEs were reallocated.

The concept to develop the B.S. in Sustainability Science program originated with the new Dean of the College, who is now the VPAA. In 2008, the president of the university challenged all deans to bring to him innovative ideas for new programs that he would fund (see above). The Dean of the College of Natural, Applied and Health Sciences proposed the sustainability program, which was approved by the president. The program received unanimous approval at the state level. In addition to sustainability being an academic program, it is also a high priority of the administration to implement sustainable practices. For example, the university has invested almost $500,000 to establish a food scraps composting program on campus. To date, this project has diverted 250,000 lbs. of food scraps from either a landfill or incinerator resulting in an avoidance of over 13 metric tons of carbon dioxide equivalent emissions and 38 million BTUs of energy use. Public relations campaigns about the university consistently highlight the sustainability program.

Motivation and mechanisms for curricular change

The interdisciplinary sustainability science academic program was developed in response to both local and global needs for scientists who can research issues that address the interaction between society and the environment and its subsequent impact. The objective was to offer a program that provides students an education necessary to understand and confront contemporary environmental, societal, and economic challenges and the interactions that occur between them. Within a 1-year period (from 2008 to 2009), a team of faculty and the dean of their college collaborated on developing the foundation of the new major, writing new course proposals associated with it, writing a program approval document, and getting the degree approved by the state. Faculty members involved with the creation of the program were from departments in the College of Natural, Applied and Health Sciences including Biology, Chemistry–Physics, Computer Science, and Earth Science. The team consisted of faculty with a mutual concern for sustainability education and an active research agenda involving environmental topics; however, none were specifically trained in or provided instruction in sustainability. Smith-Sebasto and Shebitz (2012) describe the process used to design, develop, and revise the program.

Key sustainability-learning outcomes and program goals

Table 5 lists the program mission and learning objectives. For the purpose of the program, sustainability science is defined by what it seeks to assure that graduates will be able to accomplish. The scope and sequence of the curriculum for the program is designed to prepare students to address the following four fundamental questions:

1. What are the unique characteristics of Earth that have allowed life to develop and evolve?
2. What are humans doing to compromise these characteristics?
3. Why are humans behaving in ways that compromise the characteristics?
4. What corrective actions are required to achieve sustainability?

The curriculum is designed so the students are exposed to the questions and possible answers in a deliberate and systematic manner. Courses in the first 2 years of the program focus predominantly on the first two questions. Courses in the second 2 years focus predominantly on the third and fourth questions.

The major and innovative objective of the program is to position sustainability as the superordinate focus of the curriculum. Sustainability is defined as assuring that future generations are able to benefit from the life-sustaining services provided by ecosystems to the same extent as does the current generation. It is based on the principle that sustaining ecosystem services is the primary objective of sustainability initiatives and education for sustainability. Often Venn diagrams are suggested that put sustainability at the intersection of the environmental, society, and the economy. A three-legged stool is often used to explain sustainability. At Kean, sustainability is presented as three pillars placed one on top of the other (Fig 2). The bottom pillar is ecosystem services. If, as the *World Scientists' Warning to Humanity* suggests: "Human beings and the natural world are on a collision course. Human activities inflict harsh and often irreversible damage on the environment and on critical resources. If not checked, many of our current practices put at serious risk the future that we wish for human society and the plant and animal kingdoms, and may so alter the living world that it will be unable to sustain life in the manner that we know" (http://www.ucsusa.org/about/1992-world-scientists.html), it should be clear that sustaining the ability of the planet to support life supersedes all other considerations. The second pillar is the pillar of society. Sustaining the diversity of cultures and societies as well as assuring that all societies recognize the importance of the first pillar is sublime. The first pillar supports the second pillar. If the first pillar is destroyed, the second one will no longer be supported. The third pillar is the economy. Sustaining economic models that recognize the importance of the first and second pillars is critical to achieving sustainability.

Table 5. Mission and student learning outcomes (SLO) for Sustainability Science Program at Kean University

Mission: The Sustainability Science program in the Center for Sustainability Studies at Kean University, the only one of its kind in New Jersey and one of a very small number of comparable programs nationwide, has the mission of providing students from diverse backgrounds with extraordinary educational experiences, including coursework, research opportunities, and an internship, necessary to understand and confront contemporary environmental, societal, and economic issues best examined and addressed by sustainability science; to prepare them for employment in the growing fields associated with sustainability; and/or to prepare them for graduate programs in sustainability and/or law school programs associated with sustainability. The program does this by guiding students in the educational experiences that will provide them with the knowledge, skills, abilities, and experiences that will position them to demonstrate comprehension of: (1) the unique characteristics of Earth that have facilitated the development and evolution of life as we know it, (2) the human actions and behaviors that are compromising these characteristics, (3) the reasons behind why humans are acting and behaving in unsustainable ways, and (4) the solutions that will produce long-term reversal, if not elimination, of unsustainable actions and behaviors in favor of those that are sustainable. The program seeks to empower students to embrace sustainable lifestyles whereby they will serve as change agents for others in their personal and professional communities.

Student learning outcomes

Students who graduate with a B.S. in Sustainability Science should be able to:

SLO 1: Describe of the unique characteristics of Earth that have facilitated the development and evolution of life as we know it, the foundations of sustainability.
SLO 2: Name and explain the human actions and behaviors that are compromising these characteristics.
SLO 3: Identify and appraise the reasons behind why humans are acting and behaving in unsustainable ways.
SLO 4: Identify and evaluate of the solutions that will produce long-term reversal, if not elimination, of unsustainable actions and behaviors in favor of those that are sustainable.
SLO 5: Practice a commitment to sustainability and the importance of being a change agent for others.

The focus on sustainability is first and foremost in each of the courses designed for the program. So, by example, instead of students enrolling in a chemistry course and then hoping that sustainability will be addressed in it, they enroll in a sustainability course with the expectation that chemistry concepts (or calculus, or physics, or economics, or accounting, etc.) will be the predominant theme during the semester. They are, therefore, assured that they will receive the content they desire in a context appropriate for their scholarly interests.

Curricular changes

With the evolution of the major, students complete 36 semester hours of General Education Requirements, 51 semester hours (17 courses) of major requirements as part of their core requirements (see Table 6), and 38 h of major option electives. They must also complete a one-semester independent practicum or internship. The core courses provide the foundation of the program and serve as the basis for understanding the four components of the curriculum. There are no free electives in the program; however, there are at least 38 option electives. When students are roughly at the start of their junior year, they are required to self-select into one of two options: Earth systems or human systems. They are asked to think about which of the two options most appeals to them early in their first semester on campus. The Earth systems option includes upper division coursework that focuses on the atmosphere, hydrosphere, geosphere, and biosphere. It is primarily intended for students who are most interested in advanced explorations of questions 1 and 2 above. The human systems option includes upper division coursework that focuses on communications, business, infrastructure, and social concerns. It is primarily intended for students who are most interested in advanced explorations of questions 2 and 3 above. All students address question 4 in their coursework.

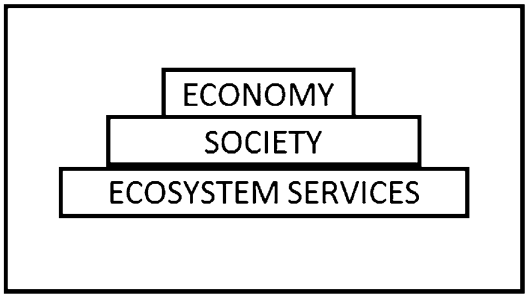

Fig. 2. Layered pillar model for sustainability used by Kean University. See text for detailed description.

The strength of the curriculum is that students are not left to question why they need to know material in their courses to pursue a career in sustainability science. More new courses are being developed to emphasize the extent to which numerous disciplines, which may seem unrelated to sustainability, can be seen through a lens of sustainability. New courses that are in the early formative stages of development include:

- History and Sustainability
- Music and Sustainability
- Art and Sustainability
- Management and Sustainability
- Marketing and Sustainability
- Social Justice and Sustainability
- Regional and Local Planning for Sustainability

Table 6. Summary of Sustainability Science required courses, credit hours, and learning objectives

Required courses	SLO1	SLO2	SLO3	SLO4	SLO5
SUST 1000: Introduction to Sustainability Science[a] (3)	I, A	I, A	I, A	I, A	I, A
SUST 1001: Biology Concepts for Sustainability I[a] (4)	I	I	I	I	I
SUST 1002: Chemistry Concepts for Sustainability I[a] (4) or CHEM 1083: Chemistry I (4)	I	I	I	I	I
SUST 1003: Earth Systems Concepts for Sustainability I (4)	I	I	I	I	I
SUST 1004: First Year Seminar on Sustainability[a] (1)	I	I	I	I	I
SUST 2001: Biology Concepts for Sustainability II[a] (4)	R	R	R	R	R
SUST 2002: Chemistry Concepts for Sustainability II[a] (4) or CHEM 1084: Chemistry II (4)	R	R	R	R	R
SUST 2003: Earth Systems Concepts for Sustainability II[a] (4)	R	R	R	R	R
SUST 2004: Second Year Seminar on Sustainability[a] (1)	R, A	R, A	R, A	R, A	R, A
SUST 2006: Mathematica Applications for Sustainability[a] (3)	R	R	R	R	R
SUST 2007: Applied Calculus for Sustainability (4) or MATH 2411: Calculus (4)	R	R	R	R	R
SUST 2009: Applied Physics for Sustainability[a] (4) or PHYS 1000: Principles of Contemporary Physics (4)	R	R	R	R	R
SUST 2203: Intercultural Communication for Sustainability[a] (3)	R	R	R	R	R
SUST 3001: Applied Statistics for Sustainability[a] (4)	R	R	R	R	R
SUST 3002: Society and Sustainability[a] (3) or SOC 3420: Environment and Society (3)	M	M	M	M	M
SUST 3003: Third Year Seminar on Sustainability[a] (1)	M	M	M	M	M
SUST 4000: Technologies for Sustainability[a] (3)	M	M	M	M	M
SUST 4001: Essential Readings in Sustainability[a] (3)	M	M	M	M	M
SUST 4003: Fourth Year Seminar on Sustainability[a] (1)	M	M	M	M	M
SUST 4300: Independent Practicum in Sustainability Science (3)	M, A	M, A	M, A	M, A	M, A

Curriculum map key: *I* introduced, *R* reinforced, *M* mastery, *A* assessment evidence collected
[a] Core requirement

Assessment

In the Fall of 2010, the first term in which students were admitted into the program, three direct measure assessments were identified.

1. At the beginning of the program in the foundation course SUST 1000: Introduction to Sustainability, baseline data will be collected to determine students' competencies regarding the program Student Learning Outcomes (SLOs).
2. At the conclusion of the second year, seminar assessment data will be collected and compared with the baseline data to determine the extent to which students have met the SLOs appropriate for that stage of the program.
3. As a pre-requisition for enrollment in the Capstone Course assessment data will be collected and compared with the baseline and mid-program data to determine the extent to which students have met the SLOs appropriate for that stage of the program and to determine the eligibility to enroll in the capstone experience.

Each subsequent year, composite data from student assessments will be collected and analyzed to address areas of program strengths and weaknesses and to inform decisions ultimately resulting in program improvements. Feedback to the program thus indicates that the students enrolled in the major are thrilled by the central theme that connects each of their courses into a whole understanding of sustainability.[2] In addition, a systematic process for

2. "The Sustainability Science major…has enveloped the key concepts of higher education and directly related them to sustainability. The core major requirements utilize classes that are required for many majors, but directly relate each class to sustainability. This is fundamental in understanding how broad the subject of sustainability is and you immediately learn that there is much more to sustainability than being 'green'. I believe the sustainability ideas should be thoroughly explained to all college students regardless of major because the environment is the foundation that upholds society and the economy." Connor B., Elizabeth, NJ

"The Sustainability Science program has gone beyond my expectations; bringing me more than just knowledge. It has made me become even more passionate about this planet. Everyday I'm asked to take action and when I do, I can proudly say that I took part in trying to save the world today." Judy H., Hamilton, NJ

"The Sustainability Science program at Kean University is an innovative and resourceful program. It taught me how to focus and develop new ideas on how humans should promote dependency on our natural environment. Since I made Sustainability Science my major, I now see the world in a different light and I am motivated to make a difference for future generations." Christina T., Sayreville, NJ

"This program has thoroughly educated me far beyond anything I could have ever expected and prepared me for the future that I am ready to build for myself and the coming generations. Eye opening hardly describes it; the knowledge gained from this program can indeed help students change the world for the better." Bryan A., Sayreville, NJ

gathering data utilizing an indirect measure, the Graduating Student Survey, was established. Data from the graduate student survey will also help inform decisions regarding program improvement to increase student learning.

The success of the program, despite its newness, has resulted in agreements with 2-year colleges in New Jersey. They are creating A.S. degrees in Sustainability with a scope and sequence of coursework that matches the first 2 years of the Kean program. Collectively, the 2-year institutions and Kean are the basis for the New Jersey Sustainability Science Education Partnership (NJSSEP). The idea is that students who complete their A.S. degree and who earn at least a 3.5 grade point average will be automatically admitted to Kean to complete their B.S. degree. Kean will waive all application fees. The ultimate plans are for students to be able to complete the 4-year Kean degree on their local campus.

The NJSSEP is also already being extended to high schools, where advanced junior and senior year students are being provided with the opportunity to enroll in SUST 1000: Introduction to Sustainability, which is taught by a teacher in their school who has met the criteria for hire as an adjunct by Kean. As long as the students earn a letter grade of 'C' or better, they will receive an official transcript from Kean verifying that they have earned three credit hours of college coursework. The motivation for the college-credit opportunity is to attract students to Kean, in general, and to the sustainability science major in particular. Efforts are ongoing to develop state and regional collaborations that inspire other colleges and universities globally to pursue the development of sustainability science programs.

The words of Nathaniel Southgate Shaler (1905), despite being over 100 years old, have and continue to guide the program development because it is clear that in many instances the conditions he described are still valid:

"Something must be done to hasten the growth of a better state of mind as to [humanity's] relation to nature by a much-needed change in our methods of teaching science. We now present the realm to beginners as a group of fragments labeled astronomy, geology, chemistry, physics, and biology, each, as set forth, appearing…as a little world in itself, with its own separate life, having little to do with its neighbors. It is rare, indeed…to find one who has gained any inkling as to the complete unity of nature. Seldom it is, even with those who attain mastery in some one of these learnings, that we find a true sense as to the absolute oneness of the realm…. This is the inevitable position of those whose task it is to advance the frontiers of knowledge (pp. 231–32)."

Summary and conclusions

Wiek et al. (2011) acknowledged that field of sustainability has not yet fulfilled its promise and argued that a key constraint is the need for new modes of education and research. He and other colleagues put the challenge this way: "linking knowledge to action for sustainability…requires a very different type of research and education… research that generates knowledge that matters to people's decisions and engages in areas where power dominates knowledge; and education that enables students to be visionary, creative and rigorous in developing solutions and that leaves the protected space of the classroom to confront the dynamics and the contradictions of the real world" (Wiek et al. 2012).

Effectively addressing this challenge is the goal for the three programs described herein and by countless other IEE and SSSE programs at colleges and universities across the U.S. Sustainability is acknowledged as the primary normative goal for IEE programs and experimentation on how to conceptualize sustainability and operationalize sustainability in IEE programs as well as in developing new SSSE academic programs is happening at an extraordinary pace.

The three case studies presented here exhibit several commonalities in the context of the learning outcomes. Each program has outcomes that are consistent with the skills, knowledge areas, and experiences identified by the roundtables on environmental systems and sustainability (Reiter et al. 2011). They all emphasize systems thinking and explicitly link human behavior and ecological processes by including opportunities for students to learn about behavioral sciences, life sciences, Earth and atmospheric sciences, social sciences, mathematics, physical sciences, and information sciences. Another important shared attribute is the recognition that a new paradigm of educational engagement needs to occur in which students are involved in inquiry along with the integration and application of knowledge to real-world problems. All three programs provide opportunities for students "to examine critically the technologies, systems of economic production, cultural systems or reproduction, laws and politics, and ideas and ideologies they currently employ for living with the rest of nature." They also help "them to reflect and act on viable alternatives" (Huckel and Sterling 1997) and provide students with opportunities "to ask the critical questions, grasp the big picture, and commit to an ethos of stewardship (how to live) and to acquire the necessary knowledge, skills, and professional training to make a real difference in the world (how to make a living)" (Bardaglio and Putman 2009).

The question of how well each of the three programs develops students' deep learning, leading them to fully integrate sustainability into their thought processes and actions, is an important question not specifically addressed in this paper. Each of the programs presented are at different stages of development; however, the commonalities in the context of learning outcomes could allow for the use of common assessment instruments to provide evidence for the extent to which the three different approaches have

been successful in the integration of sustainability concepts into the thought processes and actions of their students. Future program assessment processes will provide crucial information needed to address the issue of how differing levels and types of sustainability integration in IEE and SSSE programs facilitate the achievement of these programs' ambitious learning outcome goals.

References

Bardaglio P, Putman A (2009) *Boldly sustainable: hope and opportunity for higher education in the age of climate change.* National Association of Colleges and University Business Officers, Washington DC

Bartlett PF, Chase GW (eds) (2004) *Sustainability on campus: stories and strategies for change.* MIT Press, Cambridge

Blockstein DE, Greene J (eds) (2003) *Recommendations for education for a sustainable and secure future.* National Council for Science and the Environment, Washington, DC

Bransford JD, Brown AL, Cocking RR (eds) (2000) *How people learn: Brain, mind, experience, and school.* National Research Council. National Academy Press, Washington DC

CISCO (2008) Equipping every learner for the 21st century. http://www.cisco.com/web/about/citizenship/socio-economic/docs/GlobalEdWP.pdf Accessed 15 March 2012

Clark W (2008) Editorial: sustainability science: A room if its own. *Proc Natl Acad Sci* 104(6):1737–1738

Commoner B (1971) *The closing circle: Nature, man, and technology.* Knopf, New York

Ginsberg B, Doyle K, Cook JR (2004) *The ECO guide to careers that make a difference.* Island Press, Washington DC

Huckel J, Sterling S (eds) (1997) *Education for sustainability.* Earthscan, London

Huntzinger DN, Hutchins MJ, Gierke JS, Sutherland JW (2007) Enabling sustainable thinking in undergraduate engineering education. *Int J Eng Educ* 23(2):218–230

Kates RW, Clark WC, Corell R, Hall JM, Jaeger CC et al (2001) Sustainability science. *Science* 292(5517):641–642

Lubchenco J (1998) Entering the century of the environment: A new social contract for science. *Science* 279(5350):491–498

National Research Council (2012) Education for life and work: Developing transferable knowledge and skills in the 21st century. committee on defining deeper learning and 21st century skills. In: Pellegrino JW, Hilton ML (eds) *Board on Testing and Assessment and Board on Science Education, Division of Behavioral and Social Sciences and Education.* The National Academies Press, Washington DC

National Science Foundation AC-ERE (2003) *Complex environmental systems: Synthesis for Earth, life and society in the 21st century.* National Science Foundation, Washington DC

National Science Foundation AC-ERE (2005) *Complex environmental systems: Pathways to the future.* National Science Foundation, Washington DC

National Science Foundation AC-ERE (2009) *Transitions and tipping points in complex environmental systems.* National Science Foundation, Washington DC

Partnership for 21st Century Skills (P21) (2010) Up to the challenge: The role of career and technical education and 21st century skills in college and career readiness. http://www.p21.org/storage/documents/CTE_Oct2010.pdf Accessed 15 March, 2012

Reiter MS, Focht WJ, Bareresi PA, Bompous S, Smardon RC, Reiter KD (2011) Making education for sustainability work on your campus: The roundtables on environmental systems and sustainability. In: Filho WL (ed) *Environmental education, communication, and stustainability.* Peter Lang Ltd, Oxford, pp 61–75

Saylan C, Blumstein DT (2011) *The failure of environmental education (and how we can fix it).* University of California Press, Los Angeles

Schoolman ED, Guest JS, Bush KF, Bell AR (2012) How interdisciplinary is sustainability research? Analyzing the structure of an emerging field. *Sustain Sci* 7:67–80

Shaler NS (1905) *Man and the Earth.* Fox Duffield & Company, New York

Smith-Sebasto NJ, Shebitz DJ (2012) Creation of an innovative sustainability science undergraduate degree program: A 10-step process. *Innov High Educ* 38(2):129–141

Speth JG (2004) *Red sky at morning: America and the crisis of the global environment.* Yale University Press, New Haven

Sterling S (2004) Higher education, sustainability, and the role of systemic learning. In: Corcoran P, Wals A (eds) *Higher education and the challenge of sustainability curriculum.* Kluwer Academic Publishers, Boston

The President's Council on Sustainable Development (1996) *Sustainable American: A new consensus for prosperity, opportunity, and a health environment for the future.* U.S. Government Printing Office, Washington, DC

United Nations (1992) *Rio declaration on environment and development.* United Nations Conference on Environment and Development (UNESCO): Rio de Janerio

United Nations (2002) *Education for sustainability—from Rio to Johannesburg: Lessons learnt from a decade of commitment.* World Summit on Sustainable Development, Johannesburg

UN Millennium Project (2005) *Environment and human well-being: A practical strategy. Summary version of the report of the Task Force on Environmental Sustainability.* The Earth Institute at Columbia University, New York

van Dam-Mieras R, Lansu A, Rieckmann M, Michelsen G (2008) Development of an interdisciplinary, intercultural master's program on sustainability: Learning from the richness of diversity. *Innov High Educ* 32:251–264

Van Matre S (1990) *Earth education: A new beginning.* The Institute for Earth Education, Greenville

Vincent S (2010) *Interdisciplinary environmental education on the nation's campuses: Elements of field identity and curriculum design.* National Council for Science and the Environment, Washington DC

Vincent S, Bunn S, Stevens S (2012) *Interdisciplinary environmental and sustainability education: Results from the 2012 census of four-year colleges and universities.* National Council for Science and the Environment, Washington DC

Vincent S, Focht W (2010) In search of common ground: Exploring identity and core competencies for interdisciplinary environmental programs. *Environ Pract* 12(1):76–86

Wiek A, Farioli F, Fukushi K, Yarime M (2012) Sustainability science: Bridging the gap between science and society. *Sustain Sci* 7(1):3–4

Wiek A, Withycombe L, Redman CL (2011) Key competencies in sustainability: A reference framework for academic program development. *Sustain Sci* 6:203–218

Zemsky R (2009) *Making reform work: The case for transforming American higher education.* Rutgers University Press, Piscataway, NJ