TEACHING SUSTAINABILITY IN BUILDING DESIGN AND ENGINEERING

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ABSTRACT

Engineers and building designers make decisions that have critical impacts on the environment and society, making sensitivity to environmental and social concerns a must in the building profession. Limited pedagogical research has been conducted to develop and assess techniques for integrating sustainability into building design and engineering education. This paper describes an undergraduate course geared toward instilling concepts of sustainability in students of building-related disciplines and presents the findings of a case study and literature review conducted to identify the key features that made the course successful. The features are outlined in the form of an easy-to-use Sustainability in Higher Education Assessment Rubric (SHEAR) that faculty members can consult to shape effective programs and courses of their own to teach concepts of sustainability to their students. Two examples of this application are included, and recommendations for advancements in sustainability education are provided.

KEYWORDS

sustainability education; engineering education; environmental education; service learning

I. INTRODUCTION

A. Why Sustainability?

According to the U.S. Green Building Council (USGBC), Americans spend an average of 90% of our time indoors, making building quality and performance an extremely important factor in our health and happiness (USGBC 2005). Considering that 54 percent of U.S. energy consumption is directly or indirectly related to buildings and their construction, and that the United States consumes nearly 30 percent of the world's energy resources, the quality and performance of buildings is also a crucial factor in the health of the environment, making engineers key players in shaping more sustainable societies (Chiles 1994).

International declarations such as Agenda 21 and the World Scientists' Warning to Humanity call upon countries to make sustainability a national priority. Though overused and ambiguous, the term "sustainability" has gathered undeniable momentum in the past decade. In the context of this paper, the authors define sustainability as the practice of producing, consuming, and developing in a manner that preserves the environment, economy, and society for future generations. While being sustainable in every aspect of our lives is not a current possibility, it is a feasible goal to strive for, a goal appropriately embodied in early definitions of environmental education, which aims to produce a world population that has the knowledge, skills, attitudes, motivations, and commitment necessary to work toward solving current problems and preventing new ones (UNESCO 1975).

The U.S. Green Building Council has responded to the international community's demands by establishing the Leadership in Energy and Environmental

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Design (LEED™) rating system to assess "whole building" performance with respect to site design, energy efficiency, water consumption, material usage and indoor environmental quality. The Accrediting Board for Engineering Education (ABET) has likewise responded to emerging imperatives by setting new standards for engineering education. ABET Criterion 3a-k now requires a multi-disciplinary approach to education that instills ethics, responsibility, and awareness in engineering students in addition to the technical skills traditionally required of them so that students fully understand the impacts of their profession on the built and natural environments.

Many educators also understand the importance of sustainability and recognize the need to teach concepts of sustainability to their students; however, doing so has proven difficult for a majority of faculty members due to the intangible nature of the desired outcomes. How does one teach and measure responsibility, for example? As a result, formal sustainability education remains poorly integrated into engineering curricula, remaining compartmentalized in the specialization of environmental engineering. Consequently, duties of social responsibility and environmental sensitivity are rarely linked to technical research and education programs, and a lack of general instructional methods for fostering sustainable practices in the average engineering student remains.

B. Addressing the Sustainability Gap

Service learning and real-world projects have gained increasing popularity over the past several years as the best means to energize and engage undergraduate students in issues of sustainability. Faculty members are beginning to appreciate the multiple benefits of a hands-on approach to learning and are increasingly supportive of programs such as Engineers Without Borders and Engineers for a Sustainable World. These programs provide intimate experiences with the social and environmental impacts of engineering, enabling students to fully comprehend the importance role of sustainability in their lifestyles and careers. However, these programs are often expensive, loosely structured, and difficult to assess, making them a challenge to incorporate into everyday engineering curricula.

Seeking to aid instructors in incorporating elements of such popular programs into their courses and curricula in a rigorous, academic manner, the authors of this article launched a two-year investigation of the American Indian Housing Initiative (AIHI) course series at Penn State. The AIHI course series, a standards-based service-learning course that weaves the theme of sustainability into all of its research and assignments, was launched in 2002 to introduce students to green technologies by involving them in the application of sustainable solutions to the housing crisis facing Plains Indian tribes. Comments on exit surveys filled out by students completing the course confirmed faculty members' hopes that students would acquire an enhanced understanding of sustainability and a deeper connection to societal and environmental concerns as a result of their participation in the AIHI.

"I find myself just being more cautious about my impact on the environment, like trying to recycle more items than just plastic, and other small things like not letting the water run when I brush my teeth," recorded one student in a 2003 survey, while another student wrote, "this course exemplifies what each student should graduate understanding—you never stop learning and you learn most from the ones you are supposed to be 'helping.'" The latter comment suggests that the AIHI course series has even been successful at instilling in students the most elusive of all of ABET's new outcomes, "lifelong learning."

Interested in investigating the AIHI course series further to determine the salient features of the course and to pinpoint areas for improvement and emphasis, the authors designed an in-depth study that involved in-class discussions and a series of detailed surveys distributed throughout the year to students in the course series. Additionally, the authors conducted a literature review of four existing educational models—engineering education, environmental education, education for sustainability, and service learning—to help them identify and name the essential elements of courses geared toward instilling concepts of sustainability in students.

The overall goal of the study was to address the existing gap in building education by embedding concepts of sustainability more broadly across the curricula. As such, the study was designed so that the results would be applicable not only to the AIHI course series, but also to a variety of courses at any university. Specifically, the researchers asked, *What*

learning elements are the most important for teaching concepts of sustainability to students, and how can those elements be incorporated into existing courses and curricula in order to integrate concepts of sustainability into building education as a whole?

The study illuminated eight course elements that are presented herein as tools for faculty members in building-related discipines to (1) develop a common understanding of principles of sustainability as they relate to the disciplines; and (2) to help teach sustainability—a concept of growing importance to human society and to the building profession—to their students. The eight elements—awareness and knowledge, skill development, application in diverse settings, reflection, responsibility, diverse interactions, partnerships, and lifelong learning—constitute a pedagogy of active engagement that, like Engineers Without Borders and Engineers for a Sustainable World, bring students outside of the walls of the university to address real problems facing real communities. The elements are structured in a way that enables them to be incorporated into any investigative or research-based course, new or existing. For engineering faculty members, these eight elements represent tools for achieving the student learning outcomes stipulated by ABET Criterion 3a-k, the new "soft," or intangible, skills mandated by the accrediting board that have proven difficult to define, teach, and measure, leaving educators grappling for instructional methods that can be used to instill the new skills in our students (see Table 1).

C. Article Outline

Section II of this paper describes the AIHI course series in detail. Section III explains the research methodology undertaken by the authors in order to dissect the course series, and summarizes the findings from student surveys, in-class discussions, and focus group interviews, which provided the authors with key insights into the effectiveness of particular aspects of the AIHI course.

The fourth section presents the literature review and the identification of the eight salient elements of courses geared toward conveying concepts of sustainability to undergraduate students; it also introduces the Sustainability in Higher Education Assessment Rubric. The fifth section demonstrates an application of the rubric to two engineering courses: the AIHI course series; and the Solar Racers course. The latter case study was performed in order to demonstrate the rubric's applicability to courses that differ in structure and scope from the AIHI course series.

In the final section of this paper, the authors discuss the importance of teaching sustainability in the building disciplines in a *holistic*, *deliberate*, *well-structured* manner.

TABLE 1. "Hard" and "soft" skills of ABET Criterion 3a-k.

"Hard" Skills
An ability to apply knowledge of mathematics, science, and engineering (3.a)
An ability to design and conduct experiments, as well as to analyze and interpret data (3.b)
An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability (3.c)
An ability to identify, formulate, and solve engineering problems (3.e)
An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice (3.k)
"Soft" Skills
An ability to function on multi-disciplinary teams (3.d)
An understanding of professional and ethical responsibility (3.f)
An ability to communicate effectively (3.g)
The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context (3.h)
Recognition of the need for, and an ability to engage in lifelong learning (3.I)
A knowledge of contemporary issues (3.j)

Source: ABET 2005

II. THE AMERICAN INDIAN HOUSING INITIATIVE COURSE SERIES

A. Overview

The American Indian Housing Initiative (AIHI) is a collaborative effort between faculty members and students at the Penn State University and Chief Dull Knife College on the Northern Cheyenne Reservation. The aim of the AIHI is to address the acute housing crisis facing American Indian communities by employing sustainable building technologies to construct durable, energy-efficient homes for low-income tribal residents, who are the most poorly housed citizens in the United States (U.S. Commission on Civil Rights 2003). Students and faculty members at secondary schools and universities across the country participate in AIHI research and builds, supplementing the brainpower and manpower of the two founding institutions.

Launched at the University of Washington in 1998 as a pilot program designed to unite the teaching and discovery of strawbale construction with service to society, the AIHI has since been institutionalized at Penn State in the form of a three-part course series that engages undergraduate students in the research, development, and application of strawbale technology. Faculty members at Penn State have transformed what was originally a two-week summer program akin to Habitat for Humanity into an annual, three-part course whose research results augment the existing body of knowledge on the behavior and properties of strawbale walls and their compatibility with other green building technologies.

The specific objectives of the AIHI course series are to: (1) introduce students to green building technology through classroom lectures and small-scale laboratory experimentation; (2) develop students' abilities to manage the technological uncertainty of emerging technologies through the hands-on application of research; (3) increase students' awareness of the social, ecological, and economic impacts of building decisions by applying them in an underprivileged community; and, (4) further students' collaborative research and design skills through participation in and understanding of interdisciplinary teamwork.

In laboratory space created with funding from the National Science Foundation, graduate students guide undergraduate students in the assembly and analysis of strawbale wall specimens, whose thermal and structural characteristics and connectivity with various floor and roof systems are tested. The students' findings are applied to strawbale buildings constructed annually on the Northern Cheyenne Reservation as part of the series, an opportunity that likewise introduces students to the cultural and ethical issues associated with engineering design.

Although the AIHI course series is housed in the Department of Architectural Engineering at Penn State, it is a multi-disciplinary course that engages students from disciplines as diverse as computer engineering, art education, and nutrition. When students break into research groups during the first part of the three-part series, non-engineering students form groups geared toward making non-technical issues of concern to the Northern Cheyenne tribe accessible to the engineering students, for example the strong symbolism of the circle in native design and the lack of healthy food alternatives on the reservation. The course, therefore, offers students a holistic understanding of the people with whom they will be engaging during the second part of the series, when they travel to the reservation to put their research into practice.

B. Course Structure

The AIHI course series at Penn State is arranged so that a spring semester of lectures and research and a fall semester of critical assessment bookend the hands-on building experience in Montana. In the spring, students spend weekly class time learning about various green building technologies, including strawbale construction, as well as about general concepts of sustainability. Selected teams of students conduct guided experiments on simulated and mock strawbale wall systems while other students conduct research into Northern Cheyenne history and culture.

For some students, the lectures and research on sustainability and sustainable technologies are a first introduction to sustainability in the construction industry while for other students the lessons expand upon previously acquired concepts. For most all students, the class represents a first introduction to the current crises facing Plains tribes.

In the summer, students spend two weeks living and working on the Northern Cheyenne Reservation in Montana, where they apply the knowledge they learned in the classroom to construct durable homes

FIGURE 1. Completed AIHI projects.

Name: Early Childhood Learning Center
Year: 2005-2006
Size: 4800SF
Purpose: Provide a daycare facility for students and faculty
Technologies: Load-bearing strawbale structure, evaporative cooling, floor radiant heating, solar hot water collectors, smart dimming lighting, demand control ventilation

Name: Technology Center
Year: 2004
Size: 2400SF
Purpose: Provide a hands-on learning space and cooking lab for CDKC
Technologies: Load-bearing strawbale structure, adaptive re-use of steel structure and foundation, floor radiant heating

Name: Demonstration Home
Year: 2003
Size: 1100SF
Purpose: A small home on an existing improved lot for the NCHA
Technologies: Load-bearing strawbale structure, adaptive re-use of site utilities, structural insulated panels, insulated concrete formwork

Name: Adult Education Center
Year: 2002
Size: 1100SF
Purpose: Provide a new workspace for ABE and GED programs at Chief Dull Knife College
Technologies: Load-bearing strawbale structure, native artist mosaics

Name: Bearquiver Residence
Year: 2001
Size: 1200SF
Purpose: Build a 2BR 2 bath home using USDA Rural Development Mortgage
Technologies: Load-bearing strawbale structure, metal roofing.

and community centers in cooperation with tribal residents. During their evenings on the reservation, students visit with various Northern Cheyenne members, who share their music, landscape, and history with the students. Concepts of sustainability acquired in class are reinforced by students' interactions with tribal residents, whose economic situation and cultural beliefs call for sustainable lifestyle choices. Furthermore, students learn first hand about conservation from their daily living arrangements on the reservation, where they sleep in tents, take outdoor showers using 5-gallon solar shower bags, and have limited access to electricity.

In the fall, following the summer immersion, students reconvene to debrief and discuss their experiences as well as to document and share their work with the larger Penn State community and with future AIHI students. Sample syllabi for the spring and fall semesters are included in Appendix A.

164 students have completed the three-part AIHI course series since its inception in 2002, with approximately 26 students participating in the course each year. Over half of these students have been women, indicating that courses with a real-world focus are particularly attractive to female students, who typically comprise a minority in engineering courses. To date, students in the AIHI course series have constructed a home, a literacy center, a community center, a technology center, a sweat lodge, an early childhood learning center, and numerous outdoor spaces on the Northern Cheyenne Reservation. In the process, they have learned lessons not only about sustainable construction, but also about the importance of making decisions based as much on community needs and input as on accepted building practices. As well, AIHI collaborators have had the opportunity to update their building techniques and to incorporate new technologies into the designs of their structures, making AIHI projects increasingly environmentally and culturally friendly—in other words, making them increasingly sustainable.

C. Feedback and Reform

Initially, the AIHI course series provided students with a cursory survey of green technologies and no defined set of experiments, and with little consistency from semester to semester or from year to year. The course goals were informally addressed through ad-hoc lectures, field trips, and workshops, lending to a less-than-holistic experience. As a result, mixed feedback and critical reviews from students in the first two iterations of the series prompted the AIHI leaders to restructure the course around four specific themes created to tie the various aspects of the course into a more cohesive whole.

The four themes—sustainability and sustainable technologies, cultural awareness, multidisciplinary interaction, and teamwork and leadership—were purposefully integrated into each semester of the newly structured course series in order to maintain continuity throughout the series and from year to year. Specific activities and interactions were staged in order to give students ample opportunity to learn about each topic through real-world experience and hands-on application. For example, lessons on sustainable technologies, teamwork, and leadership were woven into a mock building activity in which one group of students leads another in the construction of a mock strawbale wall during the fall semester to practice for the summer blitz build. The first group of students passes the building knowledge along to the second group, which in turn leads a third group through the activity. This process of passing knowledge along from one group to the next becomes crucial during the summer builds, when tasks are assigned to student teams rather than to individuals—as had been the case in prior years—fostering interdependence and streamlining a previously unstructured construction process.

Additional changes made to the course series were increased opportunities for reflection, which encouraged students to continuously digest their experiences rather than miss important insights due to lack of review and contemplation. Open-ended surveys were given to students following each part of the three-part course series, prompting students to think critically about what they were learning and experiencing both in the classroom and on the reservation. Class discussions in the fall enabled students to compare their reactions with one another's and to gain additional insights into the intersection of sustainability, culture, teamwork, and the disciplines from their classmates.

Based on instructors' observations and students' feedback, the newly structured AIHI course series impacted students with the concepts of sustainability that the first two iterations of the course failed to effectively convey. Interested in identifying precisely what changes

had made the course more effective, the instructors planned a detailed research agenda for the 2004 course series, including a literature review of related instructional pedagogies whose teaching methods and corresponding learning outcomes are well documented. In the following section, the investigators explain the methodology and results of their research, leading into a discussion in Section IV of the literature review that inspired the creation of the Sustainability in Higher Education Assessment Rubric (SHEAR).

III. RESEARCH METHODOLOGY AND FINDINGS

A. Methodology

As stated in the introduction, the main research question being investigated was, What learning elements are the most important for teaching concepts of sustainability to students, and how can those elements be incorporated into existing courses and curricula in order to integrate concepts of sustainability into building education as a whole?

A case study model was chosen for the investigation since the research was exploratory in nature. The authors wanted to analyze a course whose outcomes were seemingly positive in order to identify what made the course effective. In doing so, they wanted to match effective elements of the AIHI course series with elements present in the literature on engineering education, environmental education, education for sustainability, and service learning—all widely accepted models for teaching concepts of sustainability and design to undergraduate students. A secondary goal, and a natural by-product of the research, was to further assess and document the impact of the AIHI course series on students' learning outcomes.

Data was collected by way of four in-class discussions and three reflective surveys distributed to students at the end of each section of the course series: the spring semester; the summer blitz build; and the follow-up fall semester. Twenty-five students completed the spring survey; twenty-two students completed the summer survey; and sixteen students completed the fall survey. The number of students completing the fall survey is smaller because several seniors who had begun the course in the spring graduated in August prior to the follow-up fall course. Copies of the survey are available in Appendix B.

The class discussions and surveys were framed to enable the researchers to understand what the students learned from the course; how they felt about course topics; and which elements of the course most shaped their experiences. The surveys therefore afforded students an opportunity to articulate their individual experiences with the AIHI, including lessons learned and personal commitments made to causes and/or issues related to the course. Through content analysis, survey responses were coded, recoded, and tallied to get a sense of the similarities that intersected students' reactions. The in-class discussions supplemented the survey findings. Students' comments, suggestions, and general responses were recorded on the chalkboard, tallied, and transcribed into the researchers' notes. The collective conversations enabled students to think critically about the significance of their individual reactions in light of their peers' experiences with the course series.

B. Findings

According to the completed surveys and in-class discussions, broadly experienced student outcomes of the AIHI course series were (a) an increased interest in sustainability and sustainable technologies; (b) an increased awareness of mainstream American culture and values; (c) a desire to be open-minded about other cultures and their values; and (d) the importance of diversity and communication in teamwork.

Each of these outcomes matches up with one or more of the soft skills stipulated by ABET, making them of particular interest to engineering faculty members and department heads. By the end of the course series, students were able to define sustainability holistically as well as in reference to buildings and the engineering profession (meeting ABET Criterion 3.h); to understand the impact of their fast-paced, individualistic lifestyles (meeting Criterion 3.j); to be open-minded towards other cultures and to engage competing world views (meeting Criterion 3.i); and to listen, communicate, and incorporate different ideas and approaches into the design and building processes (meeting Criterion 3.d and Criterion 3.g). These outcomes—although they align well with the criteria stipulated by ABET—are no less critical for students of other disciplines in the building profession, who likewise must learn to think and act holistically and cooperatively in order to thrive in their professional lives.

Table 2 reveals a set of responses to four questions on the fall survey, which was distributed to students at the end of their course experience. The responses are representative of the overall reactions that students had to the AIHI course series and reflect the learning outcomes identified above. Overall, the responses to the surveys distributed to students throughout the 2004 course series—the first iteration of the newly structured syllabus—were much more positive and reflected a much more holistic experience than feedback received during the first two years of the series. Students came away from the restructured course with a broader array of outcomes and a deeper sense of what those outcomes signified for themselves, for their professions, and for the world around them.

The difference in outcomes between the former AIHI course series and the restructured course series underscores the value and need for being extremely intentional and explicit in the layout and interaction of each aspect of a course with one another—in the case of the AIHI series, among lessons on sustainability and sustainable technologies, cultural awareness, multidisciplinary interaction, and teamwork and leadership—and of teaching those lessons in appropriately structured, real-world contexts using hands-on applications.

In the next section, the investigators discuss what they mean by *appropriately structured, real-world contexts* by illuminating eight particular course elements that are essential for teaching concepts of sustainability to students. They also discuss the literature review that led them to a more complete understanding of the aspects of the newly structured AIHI course series that had the biggest impact on their students.

TABLE 2. Student reflections on lessons learned in the AIHI course series.

Q1: What lessons did you learn from this experience about your own cultural biases and perceptions of other cultures?

Student Response 1: "It's amazing how much more I understand, and therefore how much less I judge, when I just try to put myself in their [tribal members'] shoes with respect to [their] priorities."

Student Response 2: "I cannot judge what other cultures dictate [. . .] based on my own understanding."

Q2: How could you translate the lessons you've learned about sustainability in this class into your career and your lifestyle?

Student Response 1: "I've learned that sustainability is an ideal that interplays between all aspects of life, and to improve the environment is difficult enough, but for true success you have to really build community as well as do all the little environmental things, such as drive less, eat right, shorter showers, etc."

Student Response 2: "The most noticeable change I have experienced is a greater desire to learn about green sustainable building techniques. As a result, I researched these topics in relation to my studio project for site analysis and precedent research."

Q3: What did you learn about yourself working as a Team Leader? How can you translate this lesson into future group work?

Student Response 1: "I learned how important it is to listen to and to respect suggestions, and how to take criticism."

Student Response 2: "It is extremely important for the leaders to setup [sic] their workers to succeed. The leaders need to ask the right questions to be able to anticipate the questions and problems that will arise from the workers. In turn, if I were to make a team, I would ensure that the team leaders would have the resources they needed, otherwise I am only setting up the team for failure."

Q4: What lessons did you learn from the various disciplines that you have interacted with in this course? This can include lessons you learned in group work or interacting with individuals.

Student Response 1: "Everyone has different takes and outlooks on all aspects of the project. We all take on tasks in different ways, but still work as a team. We all have different backgrounds and talents in [sic] which we bring to the table. We all have different experiences."

Student Response 2: "It is good to have people around that are from various backgrounds. The group is much stronger with a diverse view of ideas and knowledge."

IV. LITERATURE REVIEW AND CREATION OF THE SUSTAINABILITY IN HIGHER EDUCATION ASSESSMENT RUBRIC

The purposeful integration and interaction of lessons and activities on sustainability and sustainable technologies, cultural awareness, multidisciplinary interaction, and teamwork and leadership in the AIHI course series led to greatly enhanced student learning outcomes. These outcomes include (a) an increased interest in sustainability and sustainable technologies; (b) an increased awareness of mainstream American culture and values; (c) a desire to be open-minded about other cultures and their values; and (d) the importance of diversity and communication in teamwork.

These outcomes are in line with the new requirements stipulated by ABET, but how do they relate to the teaching of sustainability in general? Which aspects of the AIHI course series are most critical for achieving these outcomes?

Such questions prompted the investigators to conduct an extensive literature review of four widely accepted educational models both inside and outside of the field of engineering in order to better understand the relationship between course inputs and student outcomes in the AIHI series. Literature on environmental education, education for sustainability, service learning, and engineering education, was explored in depth to help the researchers make connections between the practices supported in these models and their own practices in the AIHI course series.

A. Summary of Educational Models

> "The goal of environmental education is to develop a world population that is aware of, and concerned about, the environment and its associated problems, and which has the knowledge, skills, attitudes, motivations, and commitment to work individually and collectively toward solutions of current problems and the prevention of new ones." (UNESCO 1975)

Environmental education, whose outcomes are derived from the Belgrade Charter of 1975, the Tbilisi Declaration of 1977 and the North American Association for Environmental Education (NAAEE), is premised on research demonstrating that attitudes, values, and feelings of concern for the environment play a pivotal role in prompting responsible environmental behavior. Consequently, a dominant theme in environmental education is the connection between classroom instruction and students' personal lifestyles. For students to become responsible citizens sensitive to the earth's ecosystems, students must experience and understand the interplay between their lifestyle choices and environmental processes and outcomes (UNESCO and UNEP 1977; NAAEE 1996).

Environmental education can trace its roots back to the nature study movement of the late 1800s, led by environmentalists such as John Muir and Enos Mills. In the 1930s, soil erosion, dust storms, flooding and other natural disasters expanded the national movement towards conservation. Resource management agencies and powerful writers such as Forester Aldo Leopold pushed legislators to provide schools with land for nature study purposes, while religious and other organizations developed camps and recreational facilities to promote a better understanding of the natural world (Athman and Monroe 2001). The movement continued to develop throughout the 1960s and 1970s, when the consequences of the industrial revolution, modern agricultural practices, and nuclear testing led to a new sensitivity toward "unseen forces" acting upon the environment as described by Rachel Carson in *Silent Spring*.

In 1972 the United Nations held the first international conference on the human environment in Stockholm, Germany. The Stockholm Declaration of 1972 was the first international document to call for environmental education and research. Three years later, an international environmental education workshop was hosted by the United Nations Educational, Scientific and Cultural Organization (UNESCO) in Belgrade, Yugoslavia. The Belgrade Charter, quoted above, proposed a global framework for environmental education that has been accepted by professionals in the field world wide. Two years later, in 1977, a third international conference was convened, resulting in the Tbilisi Declaration. The Tbilisi declaration identified key student learning outcomes for environmental education: awareness and sensitivity; knowledge, experience, and understanding; attitudes, values, and feelings of concern for the environment and motivation to take action; skills for identifying and solving environmental issues; and opportunity to resolve environmental problems through participation and application (1977).

The North American Association for Environmental Education (NAAEE) summarizes the outcomes desired in environmental education by stating, "Environmental education fosters skills and habits that people can use throughout their lives to understand and act on environmental issues," (NAAEE 1996). The NAAEE recommends learner-centered instruction, alternative learning techniques, expanded learning environments, interdisciplinary approaches, and connecting lessons to learners' everyday lives. Its specific suggestions for environmental educators are as follows:

- Focus on concepts, rather than focusing on facts and figures, such as environmental issues, values, quality of life, and quality of the environment;
- Teach lessons in context and connect lessons to student's everyday lives, locally and globally;
- Expose students to a variety of viewpoints and theories and give them the opportunity to explore alternative perspectives;
- Allow students to be aware of and reflect upon the diversity of cultures, races, social groups, and generations with respect and equity;
- Provide opportunities to identify environmental issues, investigate the problems, analyze the results, and evaluate the outcomes.
- Give students the chance to think critically and creatively about problems and their solutions, to make decisions, and to clarify their positions (NAAEE 1996).

Education for sustainability, premised on concepts similar to environmental education, encourages environmental literacy and personal and institutional responsibility through extra-institutional partnerships. Education for sustainability encourages student engagement in real-world projects that enable them to identify, evaluate, and solve real-world problems and expose them to different ways of thinking (Grommes 2005). Interaction with other disciplines and cultures is stressed, as is the importance of lifelong learning.

Sustainability became a buzz word in 1987, when the World Commission on Environment and Development produced the Brundtland Report, which defined sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland 1987). Sustainability has since evolved in scope and definition and is often depicted by three overlapping circles representing the interconnectedness of the environment, the community, and the economy, implying that balance only occurs when all three elements are addressed. In this way, education for sustainability appeals to a wider audience than environmental education, which focuses more exclusively on the environment.

Countries and universities around the globe took action in response to the Brundtland Report of 1987. The Talloires Declaration, created in 1990 and signed by 280 universities—including 73 from the United States—in over 40 countries calls for an action plan including raising public awareness on the need to move towards a sustainable future; establishing partnerships with primary and secondary schools; and creating programs to develop environmental literacy to all undergraduate, graduate, and professional students (1990).

Further impetus for education for sustainability came in 1992, when the United Nations Conference on Environment and Development created Agenda 21: A Call to Action. Agenda 21 calls for integrated decision making among individuals, organizations, institutions, businesses and governments in order to incorporate environmental considerations and goals into social, economic and environmental decisions, and describes education to be "a lifelong learning process that leads to an informed citizenry having the creative problem-solving skills, scientific and social literacy, and commitment to engage in responsible individual and cooperative actions" (Calder and Clugston 2003; Wheeler and Byrne 2003). Agenda 21 states that all sectors of society can and must be involved in finding solutions to environmental problems, including indigenous peoples whose knowledge, experience, and understanding can enhance education for sustainability.

The United States, under the guidance of President Bill Clinton, responded to Agenda 21 by creating the President's Council on Sustainable Development (PCSD) in 1993. Although the Council was disbanded in 1999, its recommendations for including education for sustainability in the classroom have had a lasting impact. Many authors and educators have since called for curricula that lead to an understanding of complex interactions and interconnectedness of the environment, economic, and social systems as well as an overall respect for ecological and cultural diversity among students (Wheeler and Byrne 2003).

Similar to environmental education, the most prevalent themes in education for sustainability are: ecological literacy; personal responsibility; multidisciplinary interaction; cultural diversity; diverse learning experiences; life-long learning; partnerships; and institutional responsibility (Cortese 1999; Disinger 1990).

Ecological literacy—an understanding of the natural world, how it has evolved, and how it works—is an important component of sustainability education because students need to understand natural systems in order to remedy environmental damage, restore ecosystems, and perceive the interdependence between the natural world and the human world. Multidisciplinary and interdisciplinary interaction are important in fostering collaborative working relationships between students of various disciplines and backgrounds, and in developing the communication skills required for systems thinking and integrative problem solving (Cortese 1999).

Partnerships are encouraged in education for sustainability in order to enhance educational opportunities by having students work on real-world problems those communities, governments, and industries confront. When partnerships with other educational institutions and communities are well balanced and equal, they help to strengthen institutional and community capacity to respond in a sustainable way to society's needs (Cortese; 1999; Disinger 1990; Wheeler and Byrne 2003).

Service learning, like environmental education and education for sustainability, takes the real world as its primary learning material. The National and Community Service Act of 1990 define service learning as:

> A method under which students or participants learn and develop through active participation in thoughtfully organized service that:
>
> - is conducted in and meets the needs of a community; is coordinated with an elementary school, secondary school, institution of higher education, or community service program, and with the community; and helps foster civic responsibility; and
> - is integrated into and enhances the academic curriculum of the students, or the educational components of the community service program in which the participants are enrolled; and provides structured time for the students or participants to reflect on the service experience (Section 101 (23)). (Pearson 2002)

Based on the notion that classroom lessons will come alive for students when applied to service projects in their communities, service learning is becoming increasingly popular in a growing number of schools from the elementary level up through college. Course outcomes are generally positive; however, many of these experiences focus more heavily on service and volunteerism than on learning, leaving students more interested in donating their time but not necessarily aware of the connections between their classroom studies, personal lives, and communities' needs.

Engineering education, as suggested by ABET's Criterion 3a-k, is likewise moving in the direction of environmental education, education for sustainability, and service learning. Students are not only expected to develop the skills necessary to evaluate and solve engineering problems but also to conceive of problems in terms of the environment and society, not merely efficiency and safety. Real-world lessons and experiences that engage students in critical thinking and teamwork will be required to manifest the outcomes now mandated by ABET (see Table 1 for a list of the "hard" and "soft" skills that must be acquired by students in engineering education).

B. Identification and Description of Key Course Elements

A careful reading of the literature on the pedagogical models described above uncovers four generally desired student learning outcomes common to all four models: (1) knowledge and awareness; (2) skill development; (3) a sense of responsibility; (4) lifelong learning.

Knowledge and awareness, as described in the literature on all of the models, stresses the need for students to exit a course with increased knowledge of contemporary issues, both social and environmental, as well as an awareness of differing world views.

Skill development, a necessary outcome of all four models, is needed for students to implement concepts learned in the classroom; as such, courses should provide students with an opportunity to develop action skills such as planning, collaboration, and critical thinking.

Responsibility, which is especially prominent in the literature on education for sustainability and en-

gineering education, reflects the desired outcome that students and faculty members develop increased commitment to minimizing environmental impacts in their personal and professional lives and that they feel personally accountable for their decisions.

Finally, *lifelong learning*, often the most difficult "soft" (intangible) skill to grasp and measure, reflects the need for students to exit a course wanting to continue their education outside of and beyond traditional schooling—that is, to always want to keep learning whether one is a "student" or not.

By examining *how* each of these outcomes is achieved by practitioners of each of the four models, the investigators were able to identify concrete strategies for bringing about these outcomes in students of building-related disciplines. In environmental education and education for sustainability, for example, teaching lessons in context and connecting them to students own lives and careers brings about the sense of responsibility desired of students. In education for sustainability and engineering education, having students work on multi-disciplinary teams and/or with diverse cultures fosters the communication and collaboration skills required of graduates; it also fosters an ethic of lifelong learning in students by demonstrating to them that there are countless ways of conceiving of problems and solutions. Finally, in all four models, providing students with the opportunity to develop and implement solutions to real-world problems fosters the critical thinking and action skills necessary for professional success

The pedagogical practices identified above match many of the components of the AIHI course series, which aided the investigators in pinpointing the most effective features of the course. The interjection of real-world issues into the learning process; the connection of classroom lessons with contemporary concerns; and students' exposure to new concepts, cultures, and disciplines were determined to be essential components of the restructured AIHI course series. These course components—also the critical components of environmental education, education for sustainability, and service learning—were placed into categories as follows:

Application in diverse settings, supported in the literature on all four educational models as well as in the AIHI, suggests that courses provide an opportunity for students to apply knowledge, skills, and action strategies in real-world, community settings.

Diverse interactions, a component of education for sustainability, engineering education, and the AIHI course series, requires that students be exposed to individuals from various disciplines, cultures, generations, and/or socioeconomic backgrounds.

Reflection, promoted especially in environmental education and service learning, should be encouraged through structured time and/or activities that prompt students to analyze and apply their learning experiences to their everyday lives and their careers, thereby enabling them to make connections that could otherwise be lost in the rush to complete tasks and assignments.

Partnerships with communities and other entities, as promoted in education for sustainability and pursued in the AIHI, should be established, strengthened, and maintained over time to foster inter-institutional understanding and to form measurable, mutual goals.

Table 3 provides a breakdown of the four course components and four student learning outcomes gleaned from the literature review. In Section C, these eight course elements are incorporated into the Sustainability in Higher Education Assessment Rubric, a course evaluation and enhancement tool developed to improve sustainability education in engineering and related disciplines.

C. Creation of the Sustainability in Higher Education Assessment Rubric

Due to their consistent import in the literature on the four educational models as well as to their demonstrated impact in the American Indian Housing Initiative course series, the eight total course elements listed above—the four course components and four desired outcomes—were incorporated into a Sustainability in Higher Education Assessment Rubric (SHEAR), created in order to make the investigators' research accessible to a broad audience. The rubric includes concrete suggestions for how to incorporate these elements into engineering courses. The suggestions were gleaned from additional research that the investigators conducted on successful courses typifying each of the educational models investigated as well as on the American Indian Housing Initiative course series.

The rubric's 4-point scale, with rankings from 0-3—similar to ABET ratings—is intended both to show what an ideal course looks like (a course which receives a ranking of 3 in each category) as well as to suggest a step-by-step procession from

TABLE 3. Student learning outcomes and course components from base models.

	Base Educational Models and Respective Learning Elements				
SHEAR Model Components	**Engineering Education**	**Education for Sustainability**	**Environmental Education**	**Service Learning**	**AIHI Course Series**
Awareness & Knowledge	Knowledge of contemporary issues	Knowledge of environmental, social, and economic systems	Knowledge of environmental issues	Knowledge of academic subjects	Awareness of American Indian culture and history
Skill Development	Effective communication		Action skills		Familiarity with green technologies
Application in Diverse Settings (community)	Use of modern engineering skills, techniques, and tools	Learning from diverse sources and settings	Applying action skills to environmental problems	Addressing a community problem	Building a home on an American Indian reservation
Reflection			Reflections on diversity	Reflections on connections between service and learning	Reflection on connections between sustainability and culture/career/ lifestyle/etc.
Responsibility	Professional and ethical responsibility	Personal and institutional responsibility			Professional and personal responsibility
Diverse Interactions	Multidisciplinary teams	Multidisciplinary interaction and cultural diversity			Interdisciplinary project and intercultural setting
Partnerships (community)		Partnerships			Community-university partnerships
Life-long Learning	Recognition of the need to engage in lifelong learning	Continuously informed citizenry			Recognition of the need for client/ community input

non-incorporation of key course components and outcomes to full incorporation. The following section illustrates how SHEAR can be used to both assess and improve a course that aims to integrate one or more of the eight elements.

V. APPLYING THE SUSTAINABILITY IN HIGHER EDUCATION ASSESSMENT RUBRIC

The Sustainability in Higher Education Assessment Rubric (SHEAR) was created to help faculty members in engineering and other building-related disciplines to respond to changing demands in higher education, in the building profession, and in society at large by incorporating successful teaching methods and desired student learning outcomes into existing courses and curricula *without* having to expand already overwhelming course offerings and requirements. This section, by using two examples, illustrates how SHEAR can be used to modify and improve engineering and other project-based courses.

A. Application to the AIHI Course Series

The first example is the AIHI course series. Once the investigators created SHEAR, they performed a

structural assessment of the AIHI course series by ranking it according to the rubric. Not surprisingly, the successful course on which the system was partly based received an overall score of 22.5 out of 24.0 potential points in the eight categories of the rubric. This score indicates not only successes but also areas for improvement, as anything less than a 24.0 suggests that there are specific areas in which the course could be better still.

Below is a breakdown and description of the individual scores received in each of the eight categories. Readers may find it useful to compare the descriptions to the descriptions of each number ranking in SHEAR (refer to Table 4) in order to better understand how the rubric functions.

- *Knowledge and awareness:* 3.0 points for survey responses indicating that students had increased their knowledge of sustainable technologies, the importance of sustainability, and of contemporary American Indian issues, and had become aware of the usefulness and importance of incorporating different disciplinary and cultural views into their work.
- *Skill development:* 3.0 points since students had the opportunity to develop 9 skills assessed throughout the course: analysis, investigation, evaluation, communication, collaboration, planning, organization, flexibility, and inclusiveness.
- *Responsibility:* 3.0 points because a substantial majority of the students indicated a desire to incorporate sustainable practices into their lives and their careers—many of them listing specific ways they would do so—and to promote sustainability among their friends, families, and future clients.
- *Lifelong learning:* 3.0 points for the unconventional learning experience, the numerous opportunities for non-students to engage in learning, and the interest expressed by AIHI students in continuing to expand their knowledge on topics of sustainability beyond the AIHI course series.
- *Application in diverse settings:* 3.0 for its multiple settings (classroom, laboratory, and Northern Cheyenne community); its hands-on projects; and its civic engagement and community service/outreach.
- *Diverse interactions:* 3.0 due to students' exposure to other disciplines, cultures, and socioeconomic backgrounds.
- *Partnerships:* 2.5 for its four years of committed work with the Northern Cheyenne community and for the mutual goals established and pursued.
- *Reflection:* 2.0 for the in-class discussions, personal reflections, and documentation requirements incorporated into the course series.

As the scores indicate, the AIHI course series successfully promotes the four student learning outcomes incorporated into SHEAR. These outcomes may become even stronger once the partnership between AIHI and the Northern Cheyenne tribe has further matured, and if the course instructors create additional and more structured opportunities and methods for reflection, thereby strengthening the weaker two of the four course components.

B. Application to the Solar Racers Course

To test the applicability of SHEAR to courses other than the AIHI course series, the investigators used the rubric to rate a second, unrelated engineering course, the Solar Racers course. The single-semester course, now in its second year, is derived from a successful middle-school program called the National Junior Solar Sprint (JSS), sponsored by the U.S. Department of Energy, and puts students into teams to build and race small-scale solar-powered cars using photovoltaic panels and DC motors. The Solar Racers course earned an overall score of 10.0 out of 24.0 possible points, with the following breakdown:

- *Knowledge and awareness:* 1.0 for the increased knowledge of solar power and related contemporary issues.
- *Skill development:* 2.0 for the six action skills developed during the course: collaboration, communication, critical/creative thinking, decision making, justification, and evaluation.
- *Responsibility:* 1.0 for the information provided to students on the value of solar energy and how to enter into the solar energy field in their professions.
- *Lifelong learning:* 1.0 due to the students' out-of-class interactions with local middle-school students and the resulting opportunity to act as mentors and teachers.
- *Application in diverse settings:* 3.0 for the diverse learning experience offered, for the hands-on application of skills, and for the community outreach/service performed through the middle school-university partnership.

TABLE 4. Sustainability in Higher Education Assessment Rubric (SHEAR).

	0 – none	1- little	2-moderate	3 – strong
Knowledge and Awareness	Class does not provide an opportunity to develop knowledge and awareness of contemporary issues *nor* to be aware of different perspectives	Class provides an opportunity to develop awareness of contemporary issues *or* to make students aware of different perspectives	Class provides an opportunity to develop knowledge of contemporary issues *and* to make students aware of different perspectives	Class provides an opportunity to develop knowledge of multiple contemporary issues *and* to make students aware of multiple contemporary issues
Skill Development	Class does not provide an opportunity to develop skills	Class provides an opportunity to develop 1-4 skills	Class provides an opportunity to develop 5+ skills	Class provides an opportunity to develop 9+ skills
Responsibility	Class does not ask students to understand how to *nor* to express an interest in minimizing negative environmental impacts	Class asks students to understand how to *or* to express an interest in minimizing negative environmental impacts	Class asks students to understand how to *and* to express an interest in minimizing negative environmental impacts	Class asks students to understand how to and to express an interest in minimizing negative environmental impacts
Lifelong Learning	Class does not promote learning in unconventional situations *or* provide education opportunity for non-students	Class promotes learning in unconventional situations	Class provides an educational opportunity for non-students	Class promotes learning in unconventional situations *and* provides an educational opportunity for non-students
Application in Diverse Settings	Class does not provide an opportunity to work outside of the classroom	Class provides 1 of 5: a diverse learning experience; a hands-on project; civic engagement; applied research/community outreach and education; community service	Class provides 2 of 5: a diverse learning experience; a hands-on project; civic engagement; applied research/community outreach and education; community service	Class provides 3+ of 5: a diverse learning experience; a hands-on project; civic engagement; applied research/community outreach and education; community service
Diverse Interactions	Class does not expose students to other disciplines, cultures, generations, or economic backgrounds	Class exposes students to 1 of 4: other disciplines, cultures, generations, economic backgrounds	Class exposes students to 2 of 4: other disciplines, cultures, generations, economic backgrounds	Class exposes students to 3+ of 4: other disciplines, cultures, generations, economic backgrounds
Partnerships	Class does not partner with a community entity	Class has created a new working partnership with a community entity (<2 years)	Class has maintained a 2–4 year working partnership with a community entity and has created mutual goals	Class has maintained a 5+ year working partnership with a community entity and has pursued mutual goals
Reflection	Class does not provide a structured opportunity for reflection	Class provides structured reflection through 1 of 4: class discussions; thought-provoking questions; memory-jogger handouts; writing	Class provides structured reflection through 2 of 4: class discussions; thought-provoking questions; memory-jogger handouts; writing	Class provides structured reflection through 3+ of 4: class discussions; thought-provoking questions; memory-jogger handouts; writing

- *Diverse interactions:* 1.0 since students interact with a younger generation.
- *Partnerships:* 1.0 for the one-year relationship with the middle school.
- *Reflection:* 0.0 due to the lack of opportunities for reflection in the course.

Despite being limited alignment with SHEAR, the Solar Racers course incorporates nearly all of the essential elements of successful engineering courses geared toward teaching sustainability, indicating that rather than restructuring, a *deepening* of course outcomes and components could be pursued in order to increase the impact of the course. Specific improvements the instructor could make are to maintain a consistent relationship with a specific middle school and/or teacher over several years; to involve underprivileged youth in the program; to engage students from other disciplines; and to offer opportunities for reflection, all of which will likely serve to enhance the student learning outcomes of the course.

Although SHEAR is a fairly comprehensive rubric, the authors recognize that there may be many other ways to incorporate and achieve the course outcomes it encompasses—and that not every component is necessary or appropriate for every course. Therefore, faculty members should use SHEAR as a starting point for reform, adding their own ideas and insights to its suggestions, but keeping in mind that its elements are broadly supported by the literature on effective education. Existing weaknesses of SHEAR that will be addressed in future research are discussed in the final section of this article.

C. SHEAR Results: Enhanced Student Learning Outcomes

As described in the previous section, the AIHI course series aligns very closely with the course components and student learning outcomes incorporated into SHEAR. At the same time, the authors acknowledged that there was still room for improvement in the course series. Their recommendations included creating additional and more structured opportunities and methods for reflection as well as continuing to strengthen the relationship between the AIHI course series and the Northern Cheyenne Tribe.

In 2006, these recommendations were incorporated into the AIHI course series in the form of a certificate program in sustainable home maintenance. Students in the AIHI course series developed and led a series of five afternoon workshops on topics of land, water, materials, health, and energy, which were held on the reservation during the summer build. The workshops were designed to educate homeowners on simple, effective technologies and practices that can be used to save needed resources and to reduce their environmental impact. They included group discussions and hands-on activities, giving participants an opportunity to make their own cleaning products, design land development models, and identify water and energy inefficiencies. Upon completing the program, Northern Cheyenne participants received certificates in sustainability that were co-sponsored by Penn State and Chief Dull Knife College. The workshops will again be incorporated into the 2007 course series.

The new certificate program has been a boon both to student learning and growth and to the burgeoning relationship between Penn State students and tribal members. By increasing the amount of intercultural interaction and enhancing the quality of the educational exchange, the workshops are deepening the level of learning that occurs each summer on the reservation. In 2006, the AIHI course series experienced a higher level of retention than in previous years, during which a number of students dropped out of the course prior to the final semester. Furthermore, by working through the process of sharing technical knowledge with a non-technical audience, students developed a greater ability to articulate the lessons they learned in the course as evidenced by more clear and concise end-of-the-year presentations. Thus, students in the AIHI course series are not only demonstrating a desire to share what they have learned in the course with fellow students and family members, but they are also now demonstrating a strong ability to do so *effectively*.

VI. CONCLUDING REMARKS: LESSONS LEARNED AND LESSONS STILL TO BE LEARNED

A. Lessons Learned

In order for the construction industry to fully embrace the international call for sustainability, the engineering workforce must be educated in dynamic, engaging environments that offer students opportunities to inter-

act with different disciplines and to witness the social and environmental implications of design decisions. Such environments will enable students to develop the evaluative skills needed to determine the reliability and appropriateness of new technologies as well as the collaborative skills necessary to incorporate an attention to whole building systems into their future design and construction practices.

In attempting to respond to the question, *What learning elements are the most important for teaching concepts of sustainability to students, and how can those elements be incorporated into existing courses and curricula in order to integrate concepts of sustainability into building education as a whole?*, the investigators identified new teaching and learning methods that can help faculty members in engineering and building-related disciplines to better respond to the increasing importance of environmental and social sustainability in engineering education as demanded by society and as reflected in ABET Criterion 3a-k.

As outlined in the Sustainability in Higher Education Assessment Rubric (SHEAR), eight essential elements were identified in response to the investigators' question. They are: knowledge and awareness; skill development; responsibility; lifelong learning; application in diverse settings; diverse interactions; partnerships; and lifelong learning. Suggestions for the elements' incorporation into existing engineering courses are woven into SHEAR, which was demonstrated to be generally applicable for other faculty members' use. The Sustainability in Higher Education Assessment Rubric is more than just education for sustainability: it is education for sustainability plus the most successful characteristics of environmental education, service learning, and engineering education, making it a consolidated approach to teaching concepts of sustainability to university students.

In the introduction, the authors mentioned one of the challenges of extra-curricular service-learning programs as being prohibitive costs. Although the AIHI course series is an expensive program, other courses that wish to incorporate elements of SHEAR do not have to be so costly. One of the biggest expenses of the AIHI course is transportation; however, since all communities have needs and concerns that can be addressed by local colleges and universities, professors need not look farther than their own backyards to identify real-world partners and projects. By working collaboratively with community partners to identify local needs and to co-define project goals and methods, faculty members can expose their students to diverse sensitivities, disciplines, and worldviews, thereby aiding them in attaining a deeper appreciation for their impact as engineers.

America's towns and cities—as well as those abroad—are ripe with needs, concerns, challenges, creativity, skills, and potential collaborators ready to partner on projects geared towards finding solutions to their problems. The land and people outside of the university therefore provide rich material for faculty members seeking innovative ways to enliven and excite their Generation Y students, whose "incessant contact with the media—television, video games, pulp publications and the cinema" make them a challenge to engage (Carter 2003). The Sustainability in Higher Education Assessment Rubric, the authors believe, is a meaningful tool for making the university more relevant to new generations of students by turning ordinary research-based or project-based courses into profound, holistic learning experiences.

B. Lessons Still to Be Learned

Ultimately, more research is needed to validate the findings of this study. Additional emerging and well-established public scholarship courses should be assessed and the results compared in order to verify the ability of SHEAR to distinguish between weaker and stronger courses. Furthermore, the correlation between high student impact and high SHEAR scores must be established. If high SHEAR scores can be successfully correlated to higher course impacts on students' sense of social and environmental responsibility and on their understanding of concepts of sustainability, the SHEAR model could be applied with confidence by higher education faculty members seeking to create these outcomes for their students.

This latter concern will be the focus of a new phase of research to be launched by the investigators with funding from the National Science Foundation Engineering Education Program. In order to expand our understanding of the impact of SHEAR on student learning outcomes as well as of the methods of

applying SHEAR in building-related courses, the investigators will assess three additional engineering courses focused on sustainable engineering design. Specifically, the objectives of the research will be to:

1. Assess a variety of engineering courses with respect to sustainability education and public scholarship;
2. Evaluate newly developed assessment instruments for their ability to detect student gains in courses with varying levels and types of SHEAR engagement;
3. Evaluate the impact of SHEAR courses on community partners;
4. Evaluate and refine the ability of SHEAR to assist instructors in shaping well-structured courses with well-defined objectives.

The research will involve the uniform assessment of four engineering courses at two universities. The new courses involved in the research encompass a more diverse student base as well as additional instructors that have demonstrated a commitment to sustainability education in engineering. Additionally, the courses selected for this research represent a variety of partnerships, thereby enabling a correlation of varying levels of community engagement to student learning outcomes.

While the results of this next round of investigations are pending, the authors encourage engineering and other building educators to use the existing Sustainability in Higher Education Assessment Rubric to reflect on and enhance their own courses. They also invite comments, criticisms, and concerns that result from the application of SHEAR to courses at institutions beyond Penn State.

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APPENDIX A: COURSE SYLLABI

AE497H Design-Build Montana: Sustainable Housing Solutions

Introduction

This three part course series examines how sustainable building methods, including strawbale construction, can be utilized to improve housing conditions on the Northern Cheyenne Reservation. *Part I (Spring 2007*): Participate in a discussion series on American Indian culture, history and socio-politics in tandem with the study of sustainable building technologies, project and material research, and planning. *Part II* (*Summer 2007*): Spend two weeks on the Northern Cheyenne Reservation in Montana participating in the construction of a straw-bale building, working alongside students, faculty, alumnae and industry personnel from across the country. *Part III* (*Fall 2007*): Document, reflect and assess the project and the experience. Make constructive suggestions for future improvement of the AIHI course, project and program.

Course Series Goal

Provide an interdisciplinary and hands-on experience in the application of a sustainable building technologies and community-built construction methods through a culturally diverse community partnership with the Northern Cheyenne Indian tribe.

Course Objectives:

- Contribute to design and preparation of the project by participating in individual research projects.
- Gain hands-on, interdisciplinary, team leadership experience by planning and preparing a portion of the construction project.
- Understand the impact of buildings on the environment.
- Be able to define the term sustainability and describe how it relates to your career and lifestyle.
- Be aware of cultural differences in traditions and values

Course Focus

The project planned for the 6th offering of this course series will be the *MorningStar Visiting Faculty Residence (VFAC)* on the *Northern Cheyenne Indian Reservation*, Montana. The project is being constructed in the town of Lame Deer, MT on the campus of Chief Dull Knife College (CDKC). This home will be built in conjunction with the 2007 Solar Decathlon project, and is designed to serve affordable version of the Solar Decathlon MorningStar Solar Home design concept.

Class Format

Each class will include a number of activities. Each class will open with announcements, followed by a discussion topic. Students will be expected to review readings in preparation for class discussions. Class activities may include presentations or workshops. Class time will be allotted for individual research and team updates and progress reports. Students will be required to maintain a structured online diary of their impressions of class discussions and activities using ANGEL.

Each Week: Opening Announcements
Discussion of Reading
Presentation / Workshop / Discussion
Research / Team Updates / Progress Reports

Assignments

Green Team Workshop Topic

Five class teams will help develop and present a specific topical presentation on a subject critical to sustainable housing design and construction. These topics will be used this summer as the subject of workshops attended by additional students and volunteers.

Examples: Site issues, water conservation, energy efficiency, green materials, indoor air quality.

Individual Research

Each student in the class will be asked to complete an individual research or design project on a subject or project element of their choice. Research projects will be used to help inform future housing projects to be completed by AIHI. Design projects will be used to fine tune specific details of the Solar Home.

Team Project

For this service course to be successful at making a positive impact on the Northern Cheyenne Reservation, we will need to work as a team. We will set de-

fined goals and specific objectives to prepare for and accomplish our summer experience. Each student will be expected to actively seek avenues to contribute to these goals. The class will be divided into teams that will help prepare for the summer project and contribute to the course objectives.

Planning and Leadership Teams will be formed in areas of construction we will perform, for example:

—Straw wall assembly —Lath application
—Stucco —SIP Panel construction

Students are to investigate and analyze the various materials provided in preparation. Each team will create a construction and sustainability plan for their portion of the project. Plans should be organized in a "How-To" format that will help assist construction. After completing their portion of the project students will be asked to evaluate the effectiveness of their team.

SPRING DISCUSSION AND ACTIVITY OUTLINE

No.	Subject	Objective
1	Introduction	Manage expectations, provide history and trajectory of course
2	Northern Cheyenne History	Familiarity with Cheyenne history
3	AIHI Building System	Understand AIHI building process
4	At Home: Land use and housing	Learn impacts of housing on land use
5	At Home: Energy and Water	Learn strategies and techniques for energy and water conservation
6	At Home: Materials and Health	Learn impacts of housing on resource use and on health of occupants
7	Student Workshops at The Village	Gain experience sharing topics of sustainable living at a retirement community
8	Tacos and Team Building — food and the Cheyenne	Learn aspects of planning and project management through cooking Indian Tacos
9	Home design review	Gain detailed understanding of summer build
10	Strawbale workshop	Learn basics of straw construction and volunteer team leadership
11	Site planning charrette	Develop initial plan for assigned construction activity
12	Leadership styles	Learn variable forms of leadership as applied in variable circumstances
13	Cheyenne housing history	Understand contracts between past, present, and future housing solutions for the Cheyenne
14	Presentation of work plans	Gain experience sharing work plans with volunteers
15	Packing for Montana	Complete final preparations for summer trip

FALL DISCUSSION AND ACTIVITY OUTLINE

No.	Topic	Objective
1	Re-acquaint and review	Review goals for fall course and images from summer
2	Discussion: Culture	Reflect on interaction with another culture
3	Discussion: Leadership and Teams	Reflect upon leadership and follower-ship experiences
4	Discussion: Interdisciplinary interaction	Reflect upon experience working in an interdisciplinary class in diverse settings
5	Discussion: Sustainability	Reflect on personal impacts of course on students' interaction with the environment
6	Rehearsal	Practice and obtain feedback on presentation
7	Presentation	Conduct a public presentation on your experience / recruit next year's class

APPENDIX B: STUDENT SURVEYS

Spring Reflection Survey (2004)

1. Summarize your role in your class team this semester. What team were you assigned to? What specific contributions did you make?
2. In what way would you suggest the management/organization of your group took on should be improved in future course offerings?
3. Of all the activities and events listed above, please comment on what you feel were the most meaningful experiences, and which were the least meaningful. How could they be improved?
4. How has this course shaped your perception of the term "sustainability"?
5. Do you feel that you, as a student, and as a young professional, can assist in making environmentally responsible decisions?
6. Students and Faculty involved in this course come from many different disciplines. Describe your interaction with students' faculty with disciplines different from your own. Do you feel like you have a better understanding of other disciplines as a result? Please provide a specific example.
7. On several occasions you were provided with the chance to take on a leadership role in this course. Did you take advantage of this opportunity? What did you learn from this experience? How has this experience been different or similar to experiences in other courses?
8. What problems face American Indians today? How are these problems similar or different from problems that you face in your life?

Summer Reflection Survey (2004)

1. During your two weeks on the Northern Cheyenne Reservation, what was the most meaningful experience to you?
2. Has the summer experience on the N.C. Reservation influenced or changed your perception of the environment or sustainability? If so how?
3. You worked with students, faculty and community members from several different backgrounds. How did this affect your experience?
4. Has this experience changed your perception of American Indians? If so How?
5. Do you have any additional comments or suggestions that you would like to share?

Fall Reflection Survey (2004)

Cultural Awareness

1. What lessons did you learn from your interaction with the Northern Cheyenne?
2. What lessons did you learn from this experience about your own cultural biases and perceptions of other cultures?
3. How can you translate these lessons into your actions toward people of other cultures that you encounter in school, on the job, in clubs or teams, or in passing on the streets?
4. Have you continued to correspond with tribal members that you met this summer?
5. Would you return to the reservation on your own to visit with tribal members that you met?
6. Are there any additional comments or suggestions that you think would benefit the cultural interaction portion of this course?

Sustainability and Sustainable Technologies

7. How has your experience in this course series changed your perception of sustainability?
8. How can you translate the lessons you've learned about sustainability in this class into your career and lifestyle?
9. How can this course better convey lessons of sustainability in the preparation in the spring, the experience in the summer, and the reflection in the fall?
10. Are you interested in learning more about sustainability and how it can be applied to your career choices and in your life?

Teamwork and Leadership

11. What did you learn about yourself working as a Team Leader?
12. How can you translate this lesson into future group work?
13. How can the Team Leaders Activity be improved for next year?

Disciplinary Interaction

14. What lessons did you learn from the various disciplines that you have interacted with in this course? This can include lessons you learned in group work or interacting with individuals.
15. How can you translate these lessons into your life and future careers when you will be required to work with people of different disciplines and backgrounds in order to accomplish your job?