Applied Green-Building Technologies: An Interdisciplinary Public Scholarship Course

David Riley; PhD and Elizabeth Workman

Department of Architectural Engineering, Penn State

Abstract

Building construction operations significantly contribute to the degradation of the environment, through both the consumption of non-renewable natural resources and the generation of waste. Awareness is increasing, however, of design and construction strategies that can help reduce the environmental impact of the built environment, leading to rapid growth in the popularity of "green" building technologies.

These green or "sustainable" building technologies and materials are evolving at a rate that exceeds the potential for significant documentation, testing, and practice, thus presenting a challenge to architectural and engineering educators. Characterized by an integrative design process, green building projects require professionals to work in new, non-sequential ways. In addition, many of the key issues surrounding sustainable design are contested and subject to debate and misconceptions. For educators, the question arises: How do we effectively expose students to these emerging technologies, while simultaneously engaging them in the integrative design processes specific to these technologies?

This paper describes an interdisciplinary public scholarship course series offered through the Department of Architectural Engineering at Penn State University in collaboration with a sister program at the University of Washington. This three-part course offers students hands-on experiences with new and unfamiliar green technologies, such as straw-bale construction, wind and solar power, and water conservation. Students in various disciplines are provided with opportunities to participate in the design and actual construction of a building that utilizes green building strategies and technologies. To date, these projects have been used to construct six much-needed homes and community facilities on Northern Plains Indian reservations.

The design of this course is presented along with the lessons learned through its emergence as a powerful cross-discipline learning mechanism. An assessment of the course describes it effectiveness at building the collaborative and interdisciplinary skills needed for students to play leadership roles in the future of sustainable construction.

Introduction

A rapid shift is currently taking place in the design and construction of the built environment. Increasingly, importance is placed on the design and construction of buildings that are healthier for occupants, more resource efficient, and have minimal negative impact on the environment. Buildings and their construction processes represent significant contributors to energy depletion and natural resource consumption, accounting for one-sixth of the world's freshwater withdrawals, one-quarter of its wood harvest, and two-fifths of its material and energy flows, in the United States alone[1]. Considering that "54% of U.S. energy consumption is directly or indirectly related to buildings and their construction" and that energy costs continue to rise, the need to minimize the effects of buildings on the environment becomes increasingly relevant[2].

Initial efforts to create "green buildings" have lead to dramatic improvements in the design and construction of energy- and resource-efficient buildings in contrast to standard design and construction practices. In order for these technologies to achieve significant market penetration, however, codes and standards must be established for their utilization. In his paper "Alternative Building Materials and Systems—Understanding Technical Risk and Uncertainty," Dr. John Straube notes that:

> Widespread acceptance of natural materials in industrialized countries requires more than just the development and awareness of techniques. The risk and uncertainty of using natural building materials and systems must be managed to provide a product just as reliable as competing systems. // This requires detailed information of the material and system properties, both their average performance and their variability. It also requires some means to assure society that the products and materials will perform reliably and safely. This is the function of codes and standards in industrialized building materials[3].

Efforts towards the standardization and codification of green technologies include the Leadership in Energy and Environmental Design (LEEDTM) rating system, created by the US Green Building Council. LEED has helped to accelerate the growth and popularity of green buildings. By creating a standard set of definitions and evaluation criteria to assess "whole building" performance (rather separate criteria rating separate components), the LEED system helps building owners, designers, and contractors to make visible and measurable improvements in the energy efficiency and environmental performance of buildings. Accepted metrics for green buildings include improvements in the following areas:

Site Design – minimizing the impact of a building on natural ecosystems,

Energy Efficiency – creating high performance envelopes, systems, and day lighting

Water Consumption – minimizing water use by occupants and building systems,

Materials – utilizing recycled and environmentally friendly materials, and

Indoor Environmental Quality – making buildings more healthy and productive spaces.

Worldwide efforts to improve upon the design and construction of green buildings have resulted in the accelerated development of new building technologies and materials. Many of these innovations are evolving at a rate that exceeds the potential for significant documentation, experimentation, and practice. Such innovations include water reducing fixtures and geothermal heating and cooling systems. AEC professionals are constantly being asked to learn new construction techniques or to explore unfamiliar building alternatives, many of which are less proven and established than traditional building systems. As professionals explore new alternatives and depart from established comfort regions of their respective disciplines and practices, they must simultaneously reconfigure their approaches to design processes.

A widely accepted concept in green building design and construction is a shift away from linear and sequential design processes *towards a more iterative and integrated process*. This approach allows the relationships between building systems and features to be considered in more robust and efficient ways, and can lead to more minimalist design decisions in creating more elegant buildings. For example, the decision to use a more reflective paint can improve the efficiency of indirect lighting and as a result, lower cooling and mechanical system loads, thus minimizing duct and equipment sizes – a simple but dramatic improvement that would not be possible if the choice of interior finishes was left as a last-minute decision.

An integrated design process requires a critical shift in how design and construction teams function. Instead of asking architectural, structural, mechanical, electrical, lighting, and construction specialists to perform analysis and design in isolation and in a sequential manner, all parties are brought to the table earlier in the process and asked to function in a more collaborative design environment. The roles and contributions of different disciplines must be recognized by all team members to achieve success, and garner the maximum benefit from this process. The question arises: How can engineering and architecture students be prepared to function as productive contributors on integrated green design teams?

A Green Education Model

If green building design and construction is to be fully embraced, two clear and immediate challenges for engineering (and architectural) education must be elevated at both student and professional levels. First, engineers need to develop evaluative skills that will allow them to assess unfamiliar systems, and determine the reliability and appropriateness of these technologies. Second, and vitally, emerging professionals must be equipped with an attention to whole building systems and the collaborative skills inherent to the design and construction of those systems, so that the team process of integrative design works to produce the most resource-efficient, high performance building possible.

In response to these challenges, a new course series is being implemented through the Department of Architectural Engineering at Penn State. The goals and objectives of this course, which includes an innovative public scholarship component, are presented here as one pedagogical model that seeks to introduce students to green design technologies and the collaborative processes integral to the success of these technologies, while also benefiting a community in need.

Course HIStory & DESCRIPTION

Since its inception in 1998, the American Indian Housing Initiative (AIHI)—a joint effort of Penn State and the University of Washington—has constructed six homes and community facilities on reservations across the Northern Plains. These projects proved successful in demonstrating the benefits of green building technologies to the tribes, while also engaging their interest in sustainable housing alternatives. In 2001, with support from the Penn State Bowers Program for Excellence in the Design and Construction of the Built Environment, AIHI projects were incorporated into a formal three-part course at Penn State, exploring how sustainable building methods, including strawbale construction, can be utilized to improve the impoverished living conditions endemic to tribal reservations. This course series, designed by a multi-disciplined faculty team to support AIHI, is offered to students from diverse disciplines, including Engineering, Architecture, and Landscape Architecture.

Part I (Spring) of the course includes a lecture series on American Indian culture, history, and socio-politics in tandem with the study of sustainable building technologies that includes strawbale construction, passive solar strategies, water recycling, and wind power. Part II (Summer) follows with a two-week "blitz-build" on location in Montana, where Penn State students and faculty, joined by University of Washington students and faculty, collaborate with tribal members in the design and construction of a green building. Part III (Fall) concludes the course, providing students and faculty an opportunity for assessment and critical reflection of the experience, and to make recommendations for the continuous improvement of the initiative.

LESSONS LEARNED

Prior to the establishment of the AIHI course series at Penn State, AIHI projects were offered as summer building workshops, conducted on reservations throughout the Northern Plains. The short-winded nature of these summer experiences disallowed for proper relations to be established with the tribes; and, as project sites skipped from one reservation to the next, follow-up with the tribes proved more than difficult. As well, the expense and organizational time invested in summer builds far outweighed the actual learning time for students, making for a costly "crash course" in green building technologies in an unfamiliar cultural and socio-economic environment. It was clear to AIHI collaborators that there existed a wealth of educational benefits, for both the university and tribal communities, in this opportunity; the challenge, then, was designing a pedagogical model that would harness this potential in ways that significantly impacted students as well as the communities in which they served.

In response, collaborators at Penn State designed the three-part course series to enhance students' interface with green technologies, while also providing them with time for critical inquiry and reflection into the ethical, social, and cultural implications of their experiences. The first iteration of this series, completed in Fall 2002, was centered on the design and construction of a literacy center for Chief Dull Knife College on the Northern Cheyenne Reservation in Montana. The tribal college proved to be an ideal host, providing a large office and meeting space for AIHI operations, as well as helping collaborators form alliances within the Northern

Cheyenne community.

There was a sense, though, among students and faculty, that AIHI lacked a centralized purpose, its future still in question: Would AIHI continue to work with the Northern Cheyenne Tribe? If so, how and through what ways? These questions loomed large, effecting an organizational uncertainty among faculty. In the worst sense, this uncertainty was reflected upon labor-weary students as disorganization. In the best sense, they felt that they were part of something that was quite exciting, unfamiliar, and beginning. As one faculty collaborator put it: "AIHI feel like a ship that is still floating. It needs somewhere to land."

In short, the sustainability of this sustainable housing initiative was in question. It was more than apparent to AIHI collaborators that to truly gain the respect and engagement of the tribal community and to create a successful, long-term housing initiative, they must partner with a tribal entity, establishing a home base central to its projects. Because of its political neutrality, economic stability, and high-standing reputation with the Tribe, Chief Dull Knife College represented the most suitable tribal entity with which to partner. As the reservation's educational nexus, Chief Dull Knife College offered the capacity and facilities to make the most of AIHI as an educational resource. Furthermore, this partnership would provide the opportunity for AIHI to leverage funding from external sources in order to secure the resources necessary for future projects. As well, this partnership would extend AIHI as a resource dedicated to the needs of the Northern Cheyenne Tribe, but also, in the long-term, create more resources. Most importantly, though, the administration at Chief Dull Knife College, enthusiastic about the potential to improve living conditions on the reservation, *wanted* to partner with AIHI; consequently, the AIHI partnership was extended to include Chief Dull Knife College as a formal collaborator.

In effect, the first iteration of the course series, despite its environmental uncertainty, successfully demonstrated how a yearlong interdisciplinary course could serve as a vehicle to support AIHI, and simultaneously, suggested how AIHI could collaborate with and serve a tribal community through a partnership with its tribal college. The establishment of a tribal entity as a formal partner marks a critical juncture in the development of AIHI and related courses. Beginning as a seed program with broadly defined goals, AIHI is now in a position to root itself in both the tribal community and the university community with specifically targeted objectives. In defining its public purpose of service to the tribal community, AIHI must simultaneously define its research and pedagogical purpose. This extended partnership positions AIHI to delineate the roles and contributions of each partner as follows:

- **Chief Dull Knife College** provides an educational base on-site, facilitating the participation of tribal students and community members in AIHI projects.
- **The University of Washington** contributes expertise and consultation on sustainable community development.
- **Penn State** provides technical background on the effective and integrative utilization of green technologies in the design and construction process.

REFINED COURSE DESIGN & OBJECTIVES

With the lines of collaboration established and a centralized educational base on-site in Montana, AIHI now has the opportunity to truly harness its potential. The question, then: How can Penn State collaborators integrate research most effectively into the programmatic structure of the AIHI course series? With this question in mind, AIHI coursework at Penn State will focus initially on the needs and problems specific to Northern Cheyenne community. Course activities and research will reflect and respond to the needs identified by tribal collaborators. This research will then be applied to the design and construction of desperately needed buildings on the reservation.

ENHANCED RESEARCH COMPONENT

Specifically, the core activity of AIHI and its course series at Penn State will be the design and construction of transitional housing units on the Northern Cheyenne Reservation using the emerging technology of loadbearing strawbale construction. Course research will focus on the optimization of strawbale wall systems and their compatibility with solar and wind energies. This vital research is helping to refine and integrate multiple "green" technologies for use in facilities to be constructed with tribal members. Under the guidance of faculty, research assistants, and selected students who have completed the course series, students from various disciplines will build wall sections and building assemblies in an instructional laboratory to prepare them for on-site construction. These projects will then be used as test specimens for experimentation by the class with the structural and thermal properties of strawbale walls and related green technologies. Specific research objectives will assess the load-bearing capacity and insulating properties of strawbale walls—two properties of interest to various disciplines, yet for which little formal research and experimentation has been performed. As this much-needed research develops, students and faculty will be able to integrate results into experiments that explore the most effective relationship of strawbale walls with wind and solar energies in sustainable building systems.

PUBLIC APPLICATION

This research will then be applied to the design and construction of transitional housing units on the reservation. The design of a model unit will reflect the logistical and cultural needs of Northern Cheyenne people left homeless in the chronic tribal housing crisis. In collaboration with AIHI, the Northern Cheyenne Housing Authority and Chief Dull Knife College are currently developing an apprenticeship program in which tribal members will work side-by-side with students and faculty to learn how to build a transitional housing unit utilizing sustainable technologies. In turn, these indigenous apprentices will apply their gained skills to the construction of more housing units, educating more community members in the process and working towards a model of community-built sustainable housing. Each year, the developing body of research conducted through the AIHI course series at Penn State will function to further refine the technologies being applied to construction projects on the reservation and will be disseminated more broadly via technical publications.

REFINED COURSE GOALS & OBJECTIVES

The AIHI course series seeks to develop students' appreciation for the role of green building strategies and technologies in shaping the global community. Through course research, students gain a scientific knowledge for the potential of green technologies. In applying this research to the hands-on construction of a green building in a "real world" context, students develop an ethical knowledge of their practice, thereby joining scholarship with the public.

Broadly, the educational goal of the proposed program improvement is to promote an active learning process of research, experimentation, application, and assessment that cycle yearly for continuous improvement of the building technologies employed on AIHI building projects. Specifically, the AIHI course series at Penn State seeks to meet the following educational objectives:

1) Introduce students to green technologies through small-scale experimentation seeking to ultimately explore the integration and relationship of these technologies in concert;
2) Through applied research and hands-on field experiences in the Northern Cheyenne community, enable students' abilities to manage technological uncertainty in the context of the unfamiliar, while developing their critical inquiry skills; and
3) Further students' collaborative research and design skills through participation in and understanding of interdisciplinary teams.

These targeted and defined goals for the AIHI course series are intended to create a stable core of annual activities from which to extend the collaborative model to complementary educational and research units. From this beginning, AIHI will strive to engage additional courses and research programs that could bring the energy and ideas of talented faculty and students to bear upon the myriad of educational, civic, and socio-economic challenges facing American Indians.

APPLIED GREEN TECHNOLOGIES—CREATING A SENSE OF PURPOSE

In addition to integrating research into the classroom, research goals transcend the boundaries of the classroom, and are applied to hands-on experiences for students in multiple disciplines. Students learn first-hand how to integrate engineering and architectural practices, gaining decision-making and problem-solving skills in the context of unfamiliar building materials and technologies. This experience, in the context of a marginalized community, encourages and expands their understanding of the built environment, inspiring critical inquiry into their practice. Consequently, this public activity requires students to work within the confinements of an actual set of constraints—cost, energy efficiency, client values—that directly affect their decisions. Issues of ethics, culture, history, economy, politics, and race—perhaps only alluded to in a traditional classroom setting—suddenly become matters of practical concern. The learning is *active,* and the research *meaningful,* as students help to provide facilities for a community in desperate need of shelter, where energy efficiency is vital to economic stability.

ASSESSMENT

Part III of the AIHI course series is devoted entirely to engaging students (and faculty) in critical and creative reflection and multiple, related assessment activities. While participating in the documentation of the course activities through video presentations, mock-ups, and critical writing exercises, students are asked to reflect upon their preparation, on-site activities, and interdisciplinary experiences. These reflective exercises are used to assess the success of students and faculty in meeting the objectives of the course.

Assessment of critical inquiry skills is being improved through a more formal measurement of the students' improvement in how to manage uncertainty and unfamiliar technologies and systems. The mechanisms used for this assessment are discussion groups and a survey tool that asks the students to explain the need to address uncertainty with a series of structured questions and experimentation, and to provide examples of such questions for a technology covered in the course.

A second assessment tool is being incorporated to judge students' improvement in the area of functional interdisciplinary teams. The mechanisms used include a peer assessment and feedback activity in which students engage in discussion about how their teams performed. Students are then asked to provide examples of how they and their teams performed in terms of established measurements of team competencies. Finally, students are asked to describe the value of other team members, and how input from other disciplines can be used to improve the functions of their own area of study and expertise.

BROADER IMPACTS

The immediate impacts of research enhancements will greatly improve the technical rigor of the AIHI course series. Students will develop analytical skills while contributing to the developing body of knowledge of green building technologies. Broader impacts include the refinement and deployment of new technologies to underrepresented communities desperately in need of alternatives. The enhanced program will demonstrate a model of active learning for engineering and architectural pedagogies, and provide a framework and methodology for other science disciplines as well. Most importantly, this program will provide an innovative model of public scholarship and exchange between the tribal community and university community that will lay the groundwork for future mutually beneficial partnerships.

---

[1] Roodman, D., and Lenssen, N. "A Building Revolution: How Ecology and Health Concerns are Transforming Construction," *Worldwatch Paper 124,* March 1995.

[2] Chiles, Kirsten, *A Reference Guide to Resource Efficient Building Elements, 4th Edition,* ed. S. Loken, R. Miner, and T. Mumma (Missoula: Center for Resourceful Building Technology, 1994).

[3] Straube, John. "Alternative Building Materials and Systems—Understanding Technical Risk and Uncertainty," Proceedings of the First International Conference on Ecological Building Structures. San Rafael, CA, July 5-9, 2001.

DAVID RILEY is an Associate Professor at Penn State in the Department of Architectural Engineering. His research specialization is in production management and sustainable building technologies. Riley earned his BAE and PhD from Penn State. driley@engr.psu.edu

ELIZABETH WORKMAN is a Schreyer Honors Scholar graduating from Penn State University. She is currently pursuing a graduate degree from Penn State and serving as the Development Coordinator for the American Indian Housing Initiative. eaw156@psu.edu