AC 2007-2714: AN INTERDISCIPLINARY PEDAGOGICAL TEACHING APPROACH FOR ENGINEERING, IN CONJUNCTION WITH ARCHITECTURE AND CONSTRUCTION WITH SOLAR DECATHLON PROJECT

Ronald Baier, Florida International University
Instructor & Undergraduate Advisor, Department of Construction Management, College of Engineering & Computing, Florida International University

Yong Tao, Florida International University
Professor and Undergraduate Program Director, Department of Mechanical & Materials Engineering, College of Engineering & Computing, Florida International University

An Interdisciplinary Pedagogical Teaching Approach for Engineering, in Conjunction with Architecture and Construction with Solar Decathlon Project

Abstract

The delivery of knowledge at the university level, especially in colleges/schools of engineering, architecture and construction, has generally been confined to the standard classroom setting wherein subjects are taught in various courses confined to polarized areas of study in fields such as "architecture," "civil engineering," "mechanical engineering," "construction management," and so on. These individual disciplines, in turn, are then confined to segregated academic units, the "departments." In effect, this leads to the segregated development of design and construction professionals who will eventually, however, be required to work together as a team in the workplace. With the Solar Decathlon project at Florida International University (FIU) we demonstrated a fresh interdisciplinary approach to higher education, allowing students from these various departments to work together on a design/construction project, just as would be the case in the "real world." The project called for the design, construction and transportation of a 800-ft^2, modular, solar powered house to compete at the National Mall in Washington, D.C., USA, from September 27 to October 19, 2005. In a two-year period, we formed a special course in which students participated in the various phases of the project, while earning their educational credits. Assignments were based on distinct project goals, including conceptual research, design, construction (both on campus and on the National Mall), coordination, planning and scheduling, which addressed the project as a whole within its integrated parts. The outcome of this course could not be better demonstrated than the successful showcase of the house to the public on the mall, and the winning of one of the contests. Students gained a multi-disciplinary learning and hands-on experience through the successful completion of project goals during the competion while developing teamwork skills through the integrated design, construction, transportation and validation of a functional residential structure. This approach is beneficial in producing graduates better prepared for the 21st century challenges of building a sustainable energy infrastructure, with the unique, multi-disciplinary and team work experience taught by a group of multi-disciplinary faculty. This paper documents in detail the teaching approach, project milestones, student achievements and evaluation of the project.

Keywords

Pedagogical Teaching Approach, Solar Decathlon, Interdisciplinary, Teamwork

1.0 Introduction

1.1 Solar Decathlon

2.0 The Solar Decathlon is a student competition **Introduction**

2.1 Solar Decathlon

The Solar Decathlon is a student competition sponsored by the United States Department of Energy (DOE) through its National Renewable Energy Laboratory (NREL),[1] involving universities from around the world. It is fashioned after the Olympic decathlon and, like its namesake, consists of ten contests testing performance in selected skills. However, instead of focusing on athletic ability, the Solar Decathlon spotlights the application of solar energy and other sustainable building techniques to the construction of residential structures. Its purpose is to illustrate the feasibility and encourage the use of alternative energy sources and renewable energy technologies in a contemporary context. The first Solar Decathlon was held in 2002 and has since evolved into a serial event.

Student teams from selected universities are challenged with the design and construction of a small, portable single family home powered completely by solar energy. These homes must be able to provide sufficient energy to provide for the normal living requirements of an average household: Sufficient hot water for cooking, washing clothes and personal necessities, lighting, power for TV, radio, computer and other appliances and keeping a provided electric car sufficiently charged to furnish basic transportation.

In addition to providing energy, other requirements and attributes such as architecture and "curb appeal" are measured as well. Table 1 contains a list of the ten contests and the scoring points for each:

Table 1 – 2005 Solar Decathlon Contests

CONTEST	SCORING
Architecture	200 points
Dwelling	100 points
Documentation	100 points
Communications	100 points
Comfort Zone	100 points
Appliances	100 points
Hot Water	100 points
Lighting	100 points
Energy Balance	100 points
Getting Around	100 points

Some of the contests, such as energy balance and hot water, can be objectively judged by comparing measured data, while others, such as architecture and communications, are subjectively evaluated.

The 2005 Solar Decathlon, the 2nd in what has become a continuing series, took place in the fall of 2005 for a three week period between September 29 and October 19 on the National Mall in Washington, D.C., located between the U. S. Capitol Building and--but closer to--the Washington Monument.

Eighteen universities competed in the 2005 decathlon. Table 2 identifies the participants and their final scores[1]:

Table 2 – 2005 Solar Decathlon Results

Team	Overall Points	Overall Standing
Colorado	853.716	1
Cornell	826.039	2
Cal Poly	809.130	3
Virginia Tech	784.501	4
NYIT	745.614	5
Texas	721.235	6
Missouri Rolla	718.059	7
Maryland	708.592	8
Madrid	704.844	9
Pittsburgh	653.575	10
Puerto Rico	626.605	11
Crowder (MO)	625.423	12
Florida Intl	608.009	13
Canada	586.383	14
Washington State	575.215	15
RISD	571.492	16
Michigan	545.568	17
U Mass Dartmouth	326.755	18

The first week of the decathlon was devoted to mobilization of the teams and their house components on site and the construction of the solar homes. The collection of solar homes and NREL facilities for the decathlon is dubbed the "Solar Village." The village was open to the public during the middle week (October 7-16) of the competition, during which time the competition was also judged. The final week was then devoted to disassembly and demobilization. The team with the highest accumulation of points was named the overall winner of the Solar Decathlon. This award, along with awards for several other categories were then presented during an awards dinner held on Saturday evening of the 2nd week.

2.2 FIU Involvement in the Solar Decathlon

In March of 2003, a group of faculty and students were gathered around a large conference table on the second floor of the Paul L. Cejas School of Architecture Building. The meeting, which was led by Dr. Yong Xin Tao of the Department of Mechanical and Materials Engineering, was called to discuss the possibility of the involvement of FIU in the Solar Decathlon project. The concept was grand in its nature and challenging in its scope: Encourage the use of renewable energy and the precepts of sustainable construction by designing and constructing a small single family home powered completely by solar energy that would, upon completion, be able to be moved from the FIU campus in Miami, Florida to the site of the competition in Washington, D.C. and back home again after the decathlon was over. The final challenge: The design and construction must be carried out by *students*.

At the conclusion of a number of other meetings and discussions, a formal proposal was submitted to the USDOE through the NREL by the deadline of April 30, 2003 in which the project team expressed its and the University's dedication and commitment to "energy conservation, clean energy…" and to "…increase the public's awareness of the aesthetic and energy benefits of solar technologies, which in turn…" will stimulate "…accelerated research and development of renewable energy, particularly in the area of building applications."[2] On June 20, 2003 the University was formally notified that the proposal had been accepted. FIU was now one of only 18 universities in the World competing for the Solar Decathlon prize.

3.0 Problems and Objectives

3.1 Initial Considerations

Faculty realized early on that, in order to maintain continuity and student interest throughout the two-year project, some form of encouragement had to be provided by the University. During numerous meetings in the summer of 2003 the key faculty team members formulated an *interdisciplinary* approach to managing the project: Each individual department involved would create a "special topics" or "independent study" course for one credit hour devoted to the Solar Decathlon which would then be made available on a semester-by-semester basis. It was announced that each student registering for the course in his or her respective department for at least three semesters would then receive credit for one three credit required or elective course in that particular curriculum. Each of these separate classes would, of course, meet together on a regular basis in one classroom for the entire semester. A classroom with videotaping capabilities was selected so the meetings could be recorded and team progress documented. The project was officially initiated with anticipation in the fall semester of 2003.

3.2 Purpose

The purpose of this paper is to describe the development of a unique *pedagogical* approach which was utilized in bringing the Solar Decathlon project to a successful conclusion at Florida International University and how it also resulted in a meaningful academic experience for both professors and students. This will be shown through a descriptive narrative of project history and the specific milestones that had to be reached in order to achieve the desired goal.

4.0 The Project

4.1 Research

The fall semester of 2003 was devoted to research. Approximately 30 students representing four university schools or colleges-the School of Architecture, the College of Engineering, the School of Journalism and Mass Communication and the College of Arts and Sciences (Creative Writing), were present during the first class meeting, along with 5 faculty from the departments of Architecture, Mechanical Engineering, Construction Management and the Dean's Office. After initial presentations by faculty describing overall project scope and details of the Solar Decathlon requirements as defined by NREL, the syllabus for the semester, which was previously developed by faculty, was discussed: Class meetings would initially consist of a presentation by one of the faculty on a pertinent topic, such as Single Family Home Design and Technology, Photovoltaic System Fundamentals, Prefabrication in Home Design, Construction Issues, Fundraising, etc., followed by a group discussion and appropriate research assignments for the various teams, which students had been loosely divided into based on interest. This was the formative stage of the interdisciplinary team approach that would eventually evolve through the life of the project.

Another key theme that was emphasized at the beginning was to study the previous Solar Decathlon entries in order to gain some familiarity with the way other university teams approached the project. Although we maintained a strong sense of our own identity and purpose, the review of the previous decathlon assisted us somewhat with the assimilation of the Solar Decathlon "culture" and theme.

One of the goals of the fall semester was to develop a "Case Study Research Book" for the use of future teams in the coming semesters, to assist them in the performance of their tasks. The Research Book eventually comprised a collection of the results of the various research team assignments relative to the topics noted above. Interdisciplinary teams used their particular fields of expertise to best advantage in producing useful information. This turned out to be of immense value in the spring semester, which was devoted to "design."

3.2 Design

The beginning of the spring semester, as well as the beginning of the new year of 2004, also was truly the real beginning of the project: The Design. The School of Architecture traditionally "kicks off" the spring semester with a design *charrette* for the entire school. This year's assignment: The Solar Decathlon. The design program included the following criteria:

- Under roof floor area limited to 800 square feet
- Building powered completely by solar energy
- Construction should be modular for easy assembly/disassembly
- Design to be presented on one 24" X 36" illustration board

As an inducement for a large turnout, 10 prizes of $200 each were offered. Over 200 entries were received. Entrants were given two weeks to prepare the design, which had to be submitted by a specific deadline. Subsequently, the designs were displayed in a large studio room in the Architecture Building and were judged by a jury consisting of faculty from the School of Architecture and the College of Engineering as well as student solar team leaders. The jury reviewed the entries over a three day period in order to select the 10 finalists. The solar decathlon architectural student design team then selected the top 5 from that group for consideration for the actual project design. The final design of the solar house then evolved as a conglomeration of these designs over the next four months, or so, to the more or less final configuration that was utilized. In reality, the design process continued almost to the start of fabrication of the modules as a result of not only architectural considerations, but, of course, engineering ones as well. In addition, one of the other major factors driving the design was the issue of fund raising, or sometimes, the lack thereof. Difficulty in finding funding or sponsors for the various components of the building often led to design revisions or modifications throughout the design process. Obviously, as with any construction project, financing and the availability of funds played a major role. Figure 1 shows the designs of selected top entry winners, as determined by a group of juries consisting of faculty and students of the FIU Solar Decathlon team.

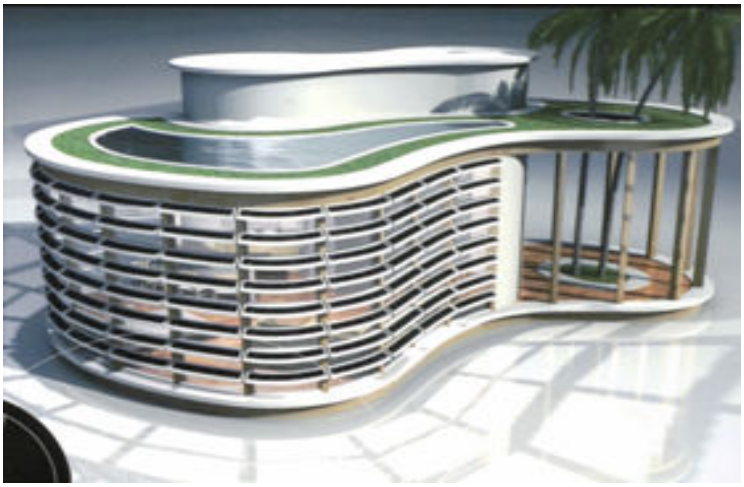

Figure 1

Various features and concepts from the top-ranked entries were adopted and incorporated into the final design prepared by student design team, under the advisement of faculty.

Figure 2 illustrates the final design of the FIU solar house.

Figure 2

3.3 Challenges in Fund-raising and Construction

After the initial design phase was completed in the summer 2004, the project entered the fund raising and pre-construction phase, which continued until early 2005. The project-led learning experience also continued through the offering of special project courses (Engineering disciplines), and a Solar Decathlon course in Architecture. The project team continued to essentially meet once a week during scheduled course hours, reporting project progress and discussing ongoing and upcoming tasks. During this period, the student team leader was given the chance to lead the class meeting, and the multi-disciplined class was divided into several groups, each taking on a different responsibility in such tasks as contacting

vendors/sponsors, publicizing the project through media and web site, acquiring materials and equipment, and updating the construction drawings to reflect the availability of needed building materials and products. During this period, students not only learned and applied their scientific, engineering and design knowledge but, more importantly, learned and practiced such skills as verbal and written communication, interaction and negotiation with professionals and vendors, team work and leadership.

Because of the limits in available resources and initial funding, students could not freely decide upon the desired materials and products to be used; rather, they worked around the available ones donated by sponsors and their deliverability within the tight time frame. Because of this factor, students learned how to reach the compromises that were necessary to completely build the house, disassemble it and transport it to the competition site – the National Mall in Washington, D.C. – within the allotted time. Students and faculty faced many challenges, but eventually successfully completed the construction and entered the 2005 Solar Decathlon competition.

Figure 3 shows the completed FIU solar house, its transportation process to the National Mall, and its evaluation by the competition judges.

Figure 3

3.4 Project Outcomes

The following outcomes have been achieved from the success of the FIU Solar Decathlon project:

(1) Students were able to acquire the working knowledge of alternative energy applications in the design and construction of residential buildings.
(2) Students gained a multi-disciplinary learning and hands-on experience through the successful execution of project goals and accomplishments during the competition.
(3) Students developed multi-disciplinary teamwork skills through the integrated design, construction, transportation and validation of a functional residential structure.

(4) Students acquired and demonstrated excellent oral and written communication skills.
(5) Faculty across different disciplines were able to work together and develop a team teaching capability.
(6) At this writing, ongoing research is still being conducted with respect to documenting additional pedagogical impacts the project had on participating student academic experience.

In addition to the overall ranking of 13 out of 18 teams, the FIU student team also received a first place award for Contest 9 – Energy Balance, a Phoenix award from the DOE and a best web design award from the DIY Network. The students' accomplishments were also reflected in numerous media exposures such as in the Miami Herald and Sun-Sentinel newspapers, National Public Radio, and FIU university publications. Figure 4 illustrates one of the articles appearing in Miami Herald.

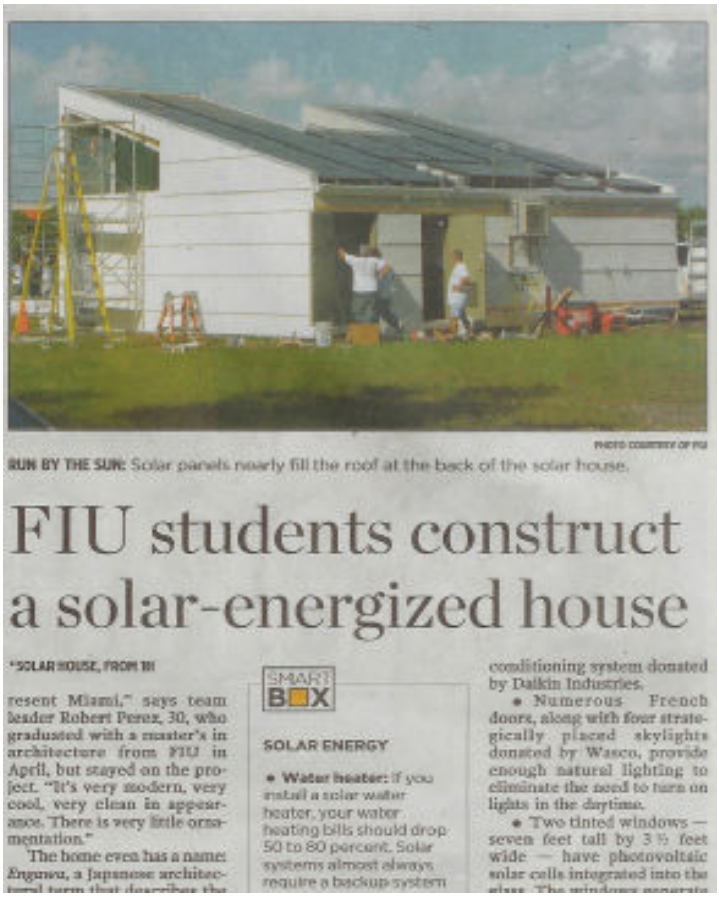

PHOTO COURTESY OF FIU

RUN BY THE SUN: Solar panels nearly fill the roof at the back of the solar house.

FIU students construct a solar-energized house

*SOLAR HOUSE, FROM 1B

resent Miami," says team leader Robert Perez, 30, who graduated with a master's in architecture from FIU in April, but stayed on the project. "It's very modern, very cool, very clean in appearance. There is very little ornamentation."

The home even has a name: *Enguwu*, a Japanese architectural term that describes the

SMART BOX

SOLAR ENERGY

• **Water heater:** If you install a solar water heater, your water heating bills should drop 50 to 80 percent. Solar systems almost always require a backup system

conditioning system donated by Daikin Industries.

• Numerous French doors, along with four strategically placed skylights donated by Wasco, provide enough natural lighting to eliminate the need to turn on lights in the daytime.

• Two tinted windows — seven feet tall by 3 ½ feet wide — have photovoltaic solar cells integrated into the

Figure 4

4.0 SUMMARY

The 2005 Solar Decathlon project at Florida International University demonstrates the successful implementation of a multi-disciplinary, project-led teaching method that enhanced the pedagogy of the existing degree programs of the colleges and schools involved. The project called for the design, construction and transportation of a 800-ft^2, modular, solar powered house to compete in the National Mall in Washington, D.C., USA, from September 27 to October 19, 2005, giving students a unique, and often described as a "once in a lifetime", opportunity in their university educational experience. The outcome of this effort could not be better demonstrated than the successful showcase of the house to the public on the mall, and winning one of contests. This approach is beneficial in producing graduates better prepared for the 21st century engineering challenges of designing and building sustainable energy infrastructure, with the unique, multi-disciplinary and team work experience taught by a group of multi-disciplinary faculty.

ACKNOWLEDGEMENTS

The Authors express their sincere appreciation to the U.S. Department of Energy and the National Renewable Energy Laboratory, more than 52 individual, industrial and commercial sponsors (see ref [2] for the complete list), Deans Prasad and Bueno and the Administration of Florida International University for their financial support to the project. Most of all, the diligent work by the students involved is gratefully acknowledged.

REFERENCES

[1] www.solardecathlon.org

[2] www.solar.fiu.edu