Confronting the Hitch: Prefab in the Classroom respecting roles, ideas, and each other

Lisa D. Iulo
The Pennsylvania State University

Abstract

An interdisciplinary team of university students, under the direction of faculty members representing different “silos” from across campus, developed and tested a Hybrid Prefabricated/Site-Built system for single-family residential construction. The project, bridging the University and maintaining momentum over four semesters and two summers, had an “Educational Footprint” that engaged over 900 students, faculty and staff. Bringing together traditionally separate disciplines, the project team was primarily led by students and faculty in architecture and architectural engineering/construction management, and represented Colleges of Engineering, Arts and Architecture, Education, Agricultural Studies, Health and Human Development, Communications, and Business. This interdisciplinary collaboration put design-build to the test in an academic setting, while preparing students to work with people from a variety of backgrounds, interests, and intentions.

While involving multiple disciplines brings comprehensive knowledge to the project, it also poses difficult challenges. Students and faculty alike were challenged with maintaining individual tasks defined by their discipline. The students had to have the self-motivation to work independently and the confidence to know when to request help, consult with others, and collaborate in a leadership role with the extended team. Team members were pushed well beyond class expectations and their comfort levels. Students were challenged with balancing their roles with the interests and intentions of other disciplines and still move ahead towards a common goal. Ideally, experience on this project helped to break down stereotypes and move beyond the traditional roles. Throughout the shifting and often frustrating process, students got to know the people behind the labels and their own capacity and capabilities.

Completion of the project required dedication, professionalism and selflessness but the process encouraged participants to break down stereotypes and move beyond traditional roles. Throughout the project the team had to define (and continually revisit) the project goals and reinvent the process for successful collaboration. This paper contends that a front-loaded, interdisciplinary process is necessary for a replicable prefabrication project and that this process should be integrated in architecture and construction curricula.

Introduction

Design-build projects, including prefabrication, offer the opportunity to demonstrate an integrated design process and a holistic approach that requires a shift from a linear design process to a multi-disciplinary, front-loaded collaboration based on feedback loops and enhanced coordination. This shift in the design process and procedure is known as Integrated or Integrative Design. The shift to an Integrative Design process also requires a shift in architectural practice/professional relationships from a one-on-one service oriented industry to a research intensive, team focused, coordinative engagement. A successful collaboration requires that team members have respect for each other and that all are working towards a common goal or goals; in addition, team members must have a general understanding of each team member’s interests and expertise. The process, in practice, is difficult to achieve and different for each building project; however, the concept is worthwhile and has the promise to benefit all involved.

The U.S. Department of Energy’s (DOE) Solar Decathlon Competition is an example of a successful multidisciplinary, multi-departmental, post-secondary education project. Held in 2002, 2005 and 2007 and scheduled for the fall of 2009, the competition is, although narrowly focused on solar energy
production, a widely respected and replicated project bringing attention to cross-disciplinary collaboration. The Solar Decathlon is an international competition organized and sponsored by the DOE National Renewable Energy Laboratory. College and University students are challenged to design, build, and operate a house powered only by the sun. The competition is held around the fall solstice on the National Mall in Washington, DC. Student Decathletes have a short ten (10) days to reassemble their 800 square foot (total roof area) solar powered home on the National Mall before the homes are open to the public and the competition begins. The home construction and systems must be relatively complete and functioning, necessitating some form of prefabrication, and the entries are judged in the subjective areas of Architecture, Engineering, Market Viability and Communications. The measured contests include Comfort Zone, Appliances, Hot Water, Lighting (objective and subjective components), Energy Balance and “Getting Around.” The Pennsylvania State University (Penn State) placed fourth out of the 20 competing colleges and universities, including Technische University Darmstadt (first place), University of Maryland (second Place), Santa Clara University (third place). 1

**Project Description**

MorningStar Pennsylvania (MorningStar PA), Penn State's entry to the 2007 Solar Decathlon Competition was designed as a prototype Hybrid Prefabricated/Site-Built system for green single-family residential construction. The design-build concept combines the economic advantages of prefabrication with the merits of on-site construction through the articulation of three key areas of the home: a modular, prefabricated “Technical Core,” a site-built “Living Space,” and a connecting “Breezeway.” This hybrid system allows the more intensive components of the Technical Core – plumbing, mechanical systems, etc. – to be factory built and shipped to site. The Living Space is reasonably customizable depending on site, climate and available materials and labor conditions. The Breezeway provides for flexibility and allows for movement of air and people between the Technical Core, Living Space and the outdoors. The Penn State team pursued a design appropriate to the climate and material conditions of the University’s location in Central Pennsylvania for the competition home. The Technical Core incorporated the full bathroom, kitchen, and laundry facilities required by the competition to service a two-person household. The mechanical space was also integrated into the Technical Core and a “marriage line” incorporated into the Breezeway allows the Living Space to plug into the Technical Core. Although the home was designed for its permanent location at the Center for Sustainability at Penn State, the entire home, including the Living Space, had to be prefabricated on the University Park campus to facilitate assembly of the home on the National Mall for the Solar Decathlon competition. Materials and finishes for the

![Fig. 1. Rendering of MorningStar PA](image)

Technical Core of the home were selected to be universal and to represent the pre-manufactured intention of the Technical Core. The Living Space materials, including exposed structural steel and hardwoods, were selected to represent the permanent site location of the home in Pennsylvania. Energy-efficient, locally manufactured Structural Insulated Panels (SIPs) were employed as a panelized wall and roof system for the exterior building envelope; this system would be customized for other homes depending on site and climate conditions. Since energy was the name of the game for the NREL Solar Decathlon competition, advanced, high-performance engineering systems, especially related to solar energy, were incorporated into the project. The team’s approach was to reduce energy loads via conservation and efficiency, to effectively capture and use solar energy, and to reclaim waste energy. Cutting-edge mechanical, electrical and photovoltaic systems include four separate building integrated photovoltaic (BIPV) arrays powering both AC and DC home systems and appliances. Other interesting components include a transportable radiant floor heating system, evacuated tube solar
collectors, and a Direct Digital Control (DDC) system. An “Energy Dashboard,” occupant feedback system, helps actively educate and involve occupants in everyday decisions such as the appropriate timing of water-intensive or high-energy tasks to reduce peak loads. (Figure 1)

Fig. 2. Photograph of MorningStar MT

To test the hybrid prefabrication/site built concept, the Penn State team also built an affordable version of the design to demonstrate its market potential. MorningStar Montana (MorningStar MT), built on the Northern Cheyenne Reservation in Lame Deer, Montana, illustrates how solar energy can be a part of an energy-efficient and affordable home in low-income communities. The design for MorningStar MT was adapted from the hybrid concept developed for the competition home. The “Technical Core” was constructed by the student team at Penn State and transported to the prepared construction site in Montana. The site-built Living Space employed panelized systems and load-bearing strawbale exterior walls for easier and faster construction by volunteers. The MorningStar Technical Core concept was designed to support an inclusive construction process that employs scarce skilled labor in a safer and healthier manufacturing environment. The site-specific Living Space provides jobs for unskilled labor and takes advantage of local resources and “materials of opportunity.” This goal was assessed through a three-week volunteer “blitz-build.” (Figure 2)

Educational Footprint

An educational goal of the Penn State effort on the Solar Decathlon was to “facilitate integration across disciplines at Penn State,” ideally inspiring new collaborative research and education partnerships across the institution. A further goal of the project was to emphasize Penn State’s role as the Commonwealth of Pennsylvania’s Land Grant Institution and promote education and public outreach. Towards these ends, the project was open for any interested students and faculty to participate. The MorningStar Homes (named for the Cheyenne population known as the Morning star people) were developed through a collaborative, multi-discipline/multi-organizational effort at the Pennsylvania State University that engaged an “educational footprint” of over 900 students, faculty, and staff from across the University. Curriculum integration was coordinated through two well-established education and research programs: the Center for Sustainability at Penn State (CfS) and the American Indian Housing Initiative (AIHI). The Hybrid design concept was developed for the initial Solar Decathlon proposal, submitted in early December 2005, to support the mission of AIHI by providing a model for future homes on the Northern Cheyenne Indian Reservation. An initial team was developed in Spring 2006 by casting a wide net across the Penn State community through open design competitions, information sessions, relevant public lectures, and targeted course projects. A Core Team of approximately 20 students, guided by faculty advisors primarily in architecture and architectural engineering, coordinated project integration.² (Figure 3)

Fig. 3. “Core Team” members

Two classes, a construction management course in Architectural Engineering (AE497) and a 3-credit vertically integrated elective design studio in the department of architecture (Arch 497C), were offered in Spring 2006 to develop the conceptual design proposal. Faculty members David Riley (AE), Scott Wing (Arch) and Lisa Iulo (Arch) worked to
coordinate and integrate the two classes with the intention of establishing common goals for the project. Since this class was outside of the normal curriculum for both departments, finding common meeting times proved difficult. Periodic design presentations and coordination charrettes were organized to establish overall project goals and establish team “buy-in.” Students in the Arch 497C class successfully generated schematic designs that further developed ideas generated through University-wide green design competitions and an additional class of 100 Architectural Engineering Students (Arch 130A), consulting with the AE497 students who were developing a project schedule and researching applicable construction methods and solar-energy systems. In May 2006 a schematic design was selected for further development and refinement. Students participated in project-related internships during the summer, and design development resumed in Fall 2006 with second-year students proposing site and living strategies for the home and a third-year architectural design studio dedicating the semester to designing the exterior details, finishes, and schematic furnishings for the home. Special interest classes were offered in architecture and architectural engineering to design and develop parts of the project, including the extensive landscape and built-in furniture, and the Core Team met weekly to manage the project and plan for construction. Procurement began in Spring 2007 and the bulk of construction on both MorningStar PA and MorningStar MT took place during the summer of 2007. (Figure 4)

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**The Humpty Dumpty Dilemma**

Modular construction and the use of preassembled components are being increasingly accepted on a growing number of projects in different building sectors. These forms of prefabrication have the potential to increase speed and quality of construction, and reduce overall costs over site-built projects. According to a report by Davis, Langdon & Everest, the challenge is to extend the scope of prefabrication while still delivering “the flexibility and individuality that the client, the project team, and site conditions demand”: not just options, but genuine site and client specific design. For this potential to be fully realized, projects need to be “designed and managed with the manufacturing and
construction processes in mind, entailing earlier decision-making and the closer involvement of specialists.\textsuperscript{3} An intense and front-loaded collaboration is necessary to plan and coordinate the project from design through procurement. A multi-disciplinary integrative design process provides the opportunity for overall design coordination, further streamlining the process and having the potential to result in an improved overall product. The Penn State Solar Decathlon Team’s vision, to "bring multiple disciplines together to promote environmental stewardship and help advance Penn State’s leadership in sustainability education," strived towards this goal. Multiple disciplines and participation from diverse individuals brought multiple interests to the project. A Team Charter, signed by all team members, recognized the contribution and interests of all participants as individuals, team members, and ambassadors of Penn State. The Charter outlined the benefits of realizing individual motivation and reminded students of appropriate etiquette for meeting common goals. Recognizing a written charter is one thing, working through it quite another. This work, before the physical labor, provided valuable lessons to all involved.

The complex team goals, project-specific requirements of the Solar Decathlon project, and two-year duration of the project required moving beyond conventional class structures. Ultimately, the projects had to be realized, had to function, and had to be comprehensively presented to the public. Overall goals and a vision for the project had to be established early and reiterated throughout the process. Maintaining the vision required coordination, collaboration, and, perhaps most importantly, communication.

1) Coordination: While involving multiple disciplines brought comprehensive knowledge to the project, it also posed a difficult challenge. Students and faculty alike were pushed to balance the roles of each field and realize the complexities of the whole system while moving the project ahead in a timely fashion. A comprehensive vision and common end goals brought unity to the project. The Core Team was responsible for managing all aspects of the project, and establishing consistency throughout the Penn State Educational Footprint. Multiple specialty teams, focused on specific technical aspects of the competition, were established and supervised by project managers on the Core Team. These CORE Team members were tasked with maintaining the overall vision and overseeing the development of specific systems within the whole. Organizational charts, which had to be periodically reconfigured with changing team dynamics, outlined who was responsible for what and who to talk with regarding a specific area of the project.

2) Collaboration: The Solar Decathlon project required dedication, professionalism, and selflessness from students who are usually focused on personal goals for grades or requirements. Typically, student projects are framed to meet specific course objectives, and focus areas are compartmentalized to meet classroom goals. Design challenges are often a reiterative process. This project extended the students beyond their comfort level to make difficult decisions and solve challenging problems to reach a common goal. Classroom learning is expanded to redefine a "finished project," where the design must be finalized, and materials must be procured and installed. Students learned their strengths and discovered new abilities, but the project also required that students acknowledge their limitations and look to others for support.

3) Communication: This project necessitated moving beyond the conventional to integrate state-of-the-art materials and systems. The students had to quickly become experts in order to select appropriate products that would integrate well with the rest of the project. In addition to communicating effectively with each other, the students gained valuable experience working directly with professionals and suppliers. Communication skills, terminology, and the use of new and technologically advanced materials and systems were very challenging. The team needed to learn to be clear in presenting ideas and patient and respectful when working with one another. Working on this project helped those involved to break down stereotypes and move beyond traditional roles. The 2007 Penn State Solar Decathlon Team had the opportunity to learn this lesson throughout the project and to realize the benefits on the National Mall during the competition. Putting aside individual motivations, the team came together to realize their common goals and strategize their approach to the competition. In presenting an argument, the students learned to present not only their point of view but to establish their rationale in the context of the overall project – solving problems and seeking integration. This approach allowed the Penn
State Solar Decathlon Team to finish an impressive fourth place with their debut entry, the MorningStar Home. (Figure 5)

Fig. 5. Team Integration. Penn State Decathletes working together to strategize an approach to a Solar Decathlon competition on the National Mall in Washington, D.C. Photo by Seth Wilberding

Confronting the Hitch: Towards Discipline Integration

Through Penn State’s approach to the Solar Decathlon, students got to know the people behind the labels and in most cases came to understand their point of view. These experiences are not common in traditional academic settings. Generally, projects are curriculum-specific, and little coordination is encouraged with others outside that discipline. The students on the 2007 Penn State Solar Decathlon team gained valuable interdisciplinary skills. These students will have the ability to meaningfully contribute to complex building challenges of green building and prefabrication. Integrating design/build projects into design and construction curricula can prepare students to work together and to be better prepared to be leading participants in the Integrative Design process.

Obviously, there are limitations to such an approach. Tight curricular requirements for program accreditation, unit separation, and faculty teaching loads make it difficult to imagine a strategy for ongoing cross-disciplinary projects. The fundraising burden for a project on the scale of the Solar Decathlon is extraordinary and well beyond the normal class expectations. In addition, the Solar Decathlon and similar higher-education projects emphasizing a cross-disciplinary role risk receiving little institutional recognition or support, undermining the significant benefits that these projects offer to the university, the students, and the public at large, and marginalizing the substantial research opportunities to the involved faculty members. The nature of academia is to resist integration, allowing each discipline to focus and develop expertise in a concentrated area. Ian McHarg compared this to the Humpty Dumpty nursery rhyme, with each discipline focusing on an individual fragment of the shattered egg. However, it is time for building-related educators to overcome the boundaries and to “reconstitute the whole.” For a project to be successful, the whole systems must be considered. Like any sustainable system, prefabrication is only as good as the sum of its parts. The MorningStar project served to expose this reality to all involved, a lesson that will hopefully be carried forth.

Acknowledgements

The Pennsylvania State University Penn State Solar Decathlon Team

Notes

1 For more information about the Solar Decathlon and a complete list of participants visit www.solardecathlon.org

2 Information about Penn State’s 2007 Solar Decathlon Team, including a list of the overall “Educational Footprint” is available at www.solar.psu.edu


5 Ibid.