

Students Involvement in the Solar Decathlon Competition: Giving Context to the Classroom Experience

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This paper highlights the need for real-world experience and teaching opportunities in the construction education process. Engineering and construction graduates need to be more than knowledgeable and analytical. By taking advantage of student competitions such as the Department of Energy's Solar Decathlon program, educators and students have the opportunity to take what is being discussed in the class room and apply it in the field. For the Solar Decathlon contest the participants have to propose, design, construct, and operate a net-zero homes in an international competition. Using the Electrical Methods and Materials Course as a baseline for comparison, the authors explore the contest process and the educational experiences of three students who participated in the Purdue University entry for Solar Decathlon 2011 contest. Observations are made about what the students learned and the process they went through as they participated in the class and the competition. By contrasting the classroom experiences with the Solar Decathlon competition experiences for specific students, the authors demonstrate some of the advantages of the real-world activities available through the competition.

Key Words: Solar Decathlon, Experiential Learning, Competitions, Work Experience

Introduction

The process of what is considered engineering and construction is expanding in the ever changing global market. Engineers and construction professionals now have to do more than just problem solve (Bernold, 2005). They must be able to be innovative in design and execution utilizing creative thinking along with math and science principles. They must then be able to work within multidisciplinary teams of other industry professional and communicate effectively across those disciplines (Bernold, 2005). Consequently, the question that must be asked and answered is: does the traditional university classroom learning and education process of lecturing professors, passive note takers and anxious examinees develop the skill set that graduating professionals need? It is the belief of these authors that there needs to be more; that is, given the complexity and expense of the modern construction project a graduating student needs to have been exposed to the often harsh realities as they exist in contemporary industry in order to become effective construction professionals.

To become effective leaders the graduating construction professionals need to develop skills that the traditional academic environment cannot supply. Consequently, the challenge for construction educators is to create learning environments involving real-world problems that are meaningful and engaging to the students. They must "balance technical solutions with social, cultural, environmental, economic, and sustainability concerns, in an environment that features multidisciplinary peer interaction and mentoring" (Fiori & Songer, 2009). Participating in the Department of Energy (DOE) Solar Decathlon program is a real-world learning environment that cannot be replicated in the classroom (Grose, 2009). The students and faculty involved were challenged beyond what they would have experienced in the classroom setting and what they learned could not be replicated in the traditional university learning environment. Although this learning experience was contained within the solar decathlon program, it is not limited to this program only. The process that the students went through and lessons learned can be generalized to other school teams and other experiential projects (Grose, 2009). It provides a practical application in a real world context. Other teams experience similar processes. And collaborative and engaging learning opportunities are what students of the 21st century are wanting to be involved with (Rodgers, Runyon, Starrett, & Von Holzen, 2006).

Background

The Solar Decathlon is a biennial DOE collegiate contest to "promote and speed to market" solar powered, residential homes (Grose, 2009). It is a student competition wherein twenty universities are selected to design, build and showcase residential structures that would ultimately be relocated to a competition campus in West Potomac Park in Washington D.C. to be viewed by the general public and judged by representatives of the Department of Energy (DOE). The challenge is "design, build, and operate solar-powered houses that are cost-effective, energy-efficient, and attractive" (DOE). The project structures are homes that are designed and built to conform to the parameters set forth by the Department of Energy in an effort to showcase the use of solar power as a practical means of residential line voltage power supply. The projects are then judged according to how well they performed within those parameters.

The challenges involved in the design and construction of a "net- zero" house, that is a house that produces at least as much electricity as it consumes, were formidable. Equally formidable were the technical/logistical issues inherent in designing and constructing a building that could be disassembled and transported. Finally, reconstructing a residential dwelling, complete in all respects, in the allotted time period of seven days created educational opportunities that mirror conditions the construction manager will face in his or her professional life.

The project fielded by team Purdue ultimately placed second. The resolution was however only a small part of what was accomplished. All who were involved in the project came away with a new depth and a new found level of maturity within their specific fields of endeavor. While the classroom provides an educational framework for the process of construction management, student competitions like the Solar Decathlon, gives context to what is learned in the more traditional venue of the classroom. This paper investigates those educational opportunities and explores how those opportunities form an essential component of the process of construction management education.

Literature Review

There is a need to change the way engineering and construction education is being taught. Bernold (2005) concludes that there is radical change needed to change the education process for the construction and engineering education process. It has been suggested that an active learning approach needs to be taken beyond the traditional classroom experience. Experiential or contextual learning is gaining recognition in higher education with the introduction of coursework combined with community service or civic engagement outside of the classroom (Bringle & Hatcher, 2009). A contextual learning program needs to include a real-world problem and a real-world organization. Just like the real-world, students must apply for the positions and opportunities to work on the project, even in the classroom setting. The project needs to include classroom as well as onsite work experience. Faculty and students need to monitor and assess what they are learning through observation, daily feedback, student journals, mentoring, and other assessment tools (Fiori & Songer, 2009). The more active the learning becomes, the more the knowledge they gain and take away from the experience (Douglas, 2011).

The Solar Decathlon is an excellent and innovative way for students to combine classroom experience with onsite real-world, real time education that cannot be replicated in a classroom or lab environment. It features advances in solar homes, accelerates solar R&D, and educates both the public and the student participants to solar design, construction, and living (Walker et al., 2003). It is "real-world experience that encompasses all of the ABET outcome criteria. The Solar Decathlon gives students the opportunity to integrate all of those aspects in a single experience, and they're building something real." In 2002 a team from the University of Virginia placed second in the Solar Decathlon. The faculty advisors observed how the competition provided the "ideal vehicle" for integrating many of the guidelines set forth by ABET into the learning experience. "It demands initiative and provides leadership opportunities in project management, cost estimation and budgeting, marketing and fund-raising. It develops manual skills, communication skills, and teamwork skills. It values and develops aesthetic judgment and creativity" (Marshall, Click & Craft, 2004). Even if the teams do not place in the competition, they are all winners and they all have incredible learning opportunities going through the process. (Grose, 2009).

The Learning Experience

Over the two years working on the Solar Decathlon project, the students have the opportunity to work on a residential dwelling with a commercial caliber design submission required by the DOE. To manage the workload, track the process, and keep students working, a class was created each semester for this project. The earned credits were tied to meeting the DOE deliverables due that coincided with that semester. There were over 200 students from multiple different disciplines that worked on this project; Mechanical Engineering Technology, Building Construction Management, Interior Design, Computer Graphics Technology, Civil Engineering, Mechanical Engineering, Visual Arts and Design, Hotel Tourism Management, Industrial Engineering, and Health & Safety.

The project started with a group of students visiting the Solar Decathlon 2009 to understand the scope and sequence of the competition. The next step was the proposal writing and submission process. Once the team was notified that the proposal was accepted, teams were created to start the preliminary design process. Each team created multiple preliminary designs and was then reviewed by the entire group. Through this process, the team was able to use the collaborative design-review approach to select a single-floor plan design. The class then worked in different work groups broken up by area of focus; interior & exterior finishes, structural engineering, MEP design, estimating and cost. The preliminary design was then refined, reviewed, and construction drawings were created. The groups created shop drawings, material lists, estimates, and construction schedules. This construction packet was submitted to the "owners" (DOE) for review and comment. At the end of the design process, the students had created a 100 page plan set, a BIM model, a 500 page project and specifications manual, and a 400 page safety manual.

Once the project was approved by the owners, permits were pulled and the house was constructed by the students on a site located on campus. The students self-performed much of the home construction and worked alongside industry professionals to build and commission the home in preparation for the competition in Washington D.C. While the student construction team was working on the home, other student teams were creating the website, brochures, speaking points, tour presentations, dinner party menus and logistical plans. Once the home was completed on campus, the teams tested every system, practiced every competition, and hosted multiple open houses for the public before packing the home up for the competition. The team also spent two weeks practicing taking the house apart and putting it back together, a monumental feat unto itself. The house was taken apart again and the entire project was shipped to Washington D.C. Student managers worked with student teams to rebuild the home in seven days. They then competed in five juried and five measured contests while hosting open houses and dinner parties over the course of 10 days. Then the home was disassembled and cleared off the site in five days. Upon conclusion of the activities, many of the students had spent nearly two years of their college career working on this project.

What Did They Learn

The authors approach to this paper was to examine the development, within a specific discipline, gained by students who participated in the Decathlon project. By the end of the competition the authors were able to observe levels of competence that were evidenced by a number of ascertainable benchmarks:

1. Each of the students were taking a greater personal initiative in, and ownership of, the project; each needing less personal direction as their experience developed. This was exemplified by one student taking on a troubleshoot without any oversight whatsoever; working through the problem and only calling for consultation once the problem had been resolved.
2. Each of the students was able to identify technical issues and how to relate to them in correct terminology as well as National Building/Electrical Code references.
3. The students developed an appreciation for real deadlines as evidenced by a resolve while under pressure while in the final hours prior to inspection. The students behaved in a manner that reflected a maturity about the project despite the pressure of the moment.
4. There was a willingness among all of the students to do whatever was required to make the project come together.
5. The team concept was never taught as such but was willingly internalized as demonstrated by those leading the team as well as those who were in subordinate roles.

During the design phase, many ideas for the home were brought forth for by the student teams. Discussions ranged from calm to heated depending on the importance of the idea and functions of the home. The students had to learn to find the balance between architectural, structural, performance, and cost of each component. One discussion and design detail that was fought over for many months was the ceiling heights in the bedroom. The structural design of the home utilized structural insulated panels and created natural vaulted ceilings in the small bedrooms with the framing of the roof system. The HVAC design team wanted lower and flatted ceilings to hide ductwork and lessen the volume of heated and cooling air space. The architectural and interior design team wanted tray ceilings to add architectural interest. The construction and cost estimating team did not want to frame down the ceilings to save time and cost. And the natural vaults and volume made the smaller bedrooms feel larger. The team managers debated this issue for nine months from the preliminary plans through final construction documents. The HVAC team came up with solutions for all three options, so the debate became a standoff between the interior design and construction teams. It was agreed upon that the plans would show a tray ceiling, but before they would be constructed, the interior design team would tour the house to see how the natural vaults looked and fit into the design statement of the home. Once the home was framed, the interior design team walked through and was able to visualize the vaulted ceiling in the real perspective of the room sizes. They had an “A Ha” moment and agreed that the vaulted ceilings made the room feel larger. The students experienced how architects, engineers, and builders interact in a real-world situation. They learned each other’s terminology and how to communicate and discuss their ideas. They learned how to negotiate with each other and how to make compromises for the good of the project. When a compromise could not be reached, they learned to create a plan of action that included all stakeholders and steps to work farther through the project until the agreed upon solution could be reached.

The Decathlon project, like its real-world counterparts, had a real deadline that came complete with real consequences. Those teams that did not make their deadlines lost points. Of the twenty teams in the competition, nine failed to complete their houses within the time allowed. Those teams were assured a disappointing assessment despite much hard work. As anyone who has spent time in the field will attest; when the end is near time is dear and all are short of temper. In this, the student experience mirrored real life. As in the field, it is seemingly the case that the issues that need to be resolved at the end of the project are all in the same location within the project. Tempers did flare but the students saw the overarching need for cooler heads to prevail and worked, at times, on top of one another to accomplish their tasks. Here again, in the crucible of completion the abstract becomes real. Lab experiences allow the student to work with the tools and materials; the lab however is an artificial environment lacking the natural impediments of as well as a personal stake in the project.

One area of observation is the electrical design and construction. To illuminate specific areas of personal student development, three case studies are presented of students with no prior building experience who are or have been enrolled in an Electrical Methods and Materials Class (*** 216). Our analysis examines the experiences of three students who participated in the electrical construction component of the project and were or would soon be involved in the 216 Electrical Methods and Materials class. We focus on this group for clarity and depth of experiential understanding. That is, while the build group was comprised of 20 students (the remaining students were assigned to other duties such as hospitality, communications and logistics among other disciplines), our study group were those who had specific duties germane to the trades discipline and the class that this author has designed and teaches and therefore forms a group that allows a basis of comparison. One of the students, Tony (alias) is presently enrolled in this class. The other students, Joe and Frank (aliases), attended the 216 class last semester. All were involved in the Solar Decathlon project primarily as electrical trainees following the managers lead and instruction. Tony had the greatest exposure followed by Joe and then Frank. While all three gained from the experience, Tony, the student with the greatest exposure to the process, came away with the greatest levels of ability and, consequently, confidence despite the fact that he had only recently transferred to the Construction Management program from Engineering. Of the three, those who had prior methods and materials coursework showed greater levels of familiarity at the beginning of the construction process. Consequently, they were more “bought in” at the outset. As the project developed, however, Tony began to close the gap between him and his counterparts; in time surpassing the other two. After an initial period of acclimation he became comfortable with the process and moved easily between functions without difficulty. It was this student who, when a problem arose late in the project, undertook a troubleshoot to ascertain why a particular site lighting fixture was not working. This is a thought process and level of confidence that is usually the province of a mature practitioner with something on the line; usually remuneration. The progress and development of the students who were the subject of this analysis was assessed by a career industry professional; a licensed electrical contractor who had over 30 years of experience in project administration as well as in the associated personnel decisions that are driven by issues of scheduling and productivity. It is, after all, exactly this type of person that the graduating student will be working with when they begin their careers in industry. To repeat a point made throughout this paper; we as construction management instructors must bridge the gap between the theoretical and the practical. We therefore depend upon input from our partners in industry who help us craft a curriculum that prepares the student for what will be required of them.

The Electrical Construction Methods and Materials Course (BCM 216) is a required class for the construction management major and has two hours of class time each week as well as two hours of lab time. National Electrical Code (NEC) understanding and application are the focus of the classroom experience. Lab sessions are hands-on training sessions; students are given projects to familiarize themselves with tools and materials. The theoretical understandings for the class are found in mastery of the NEC which is a fire-prevention document published every three years and is the basis of code enforcement as adopted in each jurisdiction having authority through our the country. Most practitioners who have read and applied the NEC as a reference document appreciate the difficulty inherent in the process. The search for the required information can require several steps to locate and is therefore difficult even for the initiated as well as being fraught with opportunities for mistake. Unfortunately, without a history of methods and materials application, which would allow a tangible reference as to what the code is referring to, the citation might as well be written in Ancient Greek.

Most students have considerable difficulty making the step in cognitive processes from the theoretical as represented by the NEC to the practical: the world of conduit and wire. More importantly, the student cannot, without a context for the classroom discussion hope to gain the depth of understanding required to effectively manage a complex construction project in real time; which is what the student must achieve in order to succeed in industry. This of course is the function of the lab exercise and to an extent the lab does in fact serve that purpose; but only to an extent. Students can learn in the classroom why the Code limits how many conductors they pull into a conduit — considerations regarding heat dissipation and pulling friction. They then learn through the lab experience how it feels to pull those conductors through the pipe from junction box to junction box. What cannot be learned without more however is how all of this comes together in the often chaotic environment of the living project with several trades competing for the same work space, looming, immutable deadlines and real consequences. What also cannot be easily learned is how (or why), they can improve their conduit layout to make the process more efficient and intuitive and finally how all of this is judged by a flesh and blood electrical inspector who may or may not be in a good mood.

The nature of the electrical construction of the Decathlon project was complicated particularly for a residential project. Specifically, because the home was of modular construction, electrical feeds could not be performed in any typical manner. There was no attic or crawl space to facilitate conduit runs and the conduits provided by the supplier of the modular panels were of limited value, particularly for main runs. Further, the project had to be constructed in a manner that would allow it to be taken apart for shipment and reassembled at the competition site in Washington D.C. Finally, the project reflected levels of technical sophistication rarely seen in contemporary construction: the presence of a photovoltaic array with current inverter and associated equipment, a "bio wall" (living plants grown vertically on a wall to purify and filter return air) and web-based lighting controls are examples of this point. It should also be mentioned that the project had to be constructed according to specifications set forth by the Department of Energy and were, consequently, more stringent than any previously encountered by the participants or their faculty advisors. None of the students had any previous involvement in performing electrical work. The juxtaposition between their classroom experiences and field experiences, as well as between them and those students who did not participate in this event, are instructive.

In the discipline of managing a construction project an accurate vocabulary is crucial to developing the respect of the skilled craftspeople with whom they must interact and manage. For example, few things will cause an electrician to disregard a young manager more than to refer to a receptacle as an outlet or a lighting fixture as a lamp or conduit as a pipe. These may seem to be trivial issues, but they are benchmarks of literacy in the field. While issue identification and vocabulary are components of what we convey in class, most of it is abstract until one performs installations in real time. Joe and Frank both did well in the 216 class but were far better developed once they had repeatedly installed devices and fixtures under the pressure of the deadline. It is here that the students began to bridge the chasm between the theoretical and the practical. The terminology became real. Circuit breakers became overcurrent protection devices, neutral conductors became grounded conductors as is referenced by the NEC. What was significant was that the reference became relevant; they could understand why these devices were named in the Code in that manner.

Over the course of a construction project there is no shortage of dirty, unpleasant jobs. Construction projects routinely supply work functions that most people would consider unacceptable. The Decathlon project was true to form in this area; the students learned to get outside of their comfort zones to do what was required to move the project forward. All three students willingly and without (much) complaint did what was required. This set them in sharp contradistinction with students less animated by the spirit of the project. Whether asked to curl up in a tightly confined attic space or crawl in the mud beneath a deck, they approached hard, unpleasant duties with purpose and even a bit of humor.

Perhaps the most important lessons imparted by the students being involved in the competition were the correlative realities of working as a team and obeying the chain of command; leading and following. Construction management is a function of imposing one's leadership upon a group of people to initiate and maintain momentum throughout the course of a project. Without this momentum the project will never be profitable. The authors have observed a well run project is like a finely tuned machine; all parts working well together. This can only be achieved through the team spirit that flows from effective leadership. Effective leadership is the learned skill of causing other people to want to do what the manager needs them to do. Unless all who are involved in the project are functioning as an almost organic whole, the project will suffer. The natural tendency of any project is anarchy unless it is staffed by effective leaders and those willing to accept that leadership for the good of the project. Leadership and teamwork are not something people know without being taught and they are almost impossible to teach in a classroom environment. Faculty can speak the words from the lectern but the functional realities of these dynamics can only be learned and appreciated in the give and take of the field. In the Solar Decathlon competition students learned through immersion in the process that teamwork and leadership were the unspoken cornerstones of the well run project. It is this understanding that will help equip the construction management student for a successful career in industry and it is exactly this that constitutes depth of understanding.

Conclusion

The authors understand that the diligent student who reads the assigned materials in a given class, participates in class and is adept at examsmanship can earn the "A" without the benefit of having participated in a construction competition. What cannot be so easily earned is exactly that which the student must leave school with: depth of understanding. The authors were privileged to have witnessed, and perhaps have been instrumental in, guiding several students as they gained that depth over the period of months that represented the preparation and construction of the Solar Decathlon project. Through this experience it has become clear that competitions such as the Solar Decathlon provide identifiable and valuable additions to the education of students of applied engineering. Development of future opportunities for construction management students to participate in "real-world" experiences of this type should be encouraged. Additional opportunities exist in the detailed study of educational outcomes from competitions to help guide the design and administration of these competitions. Although significant student development can be identified through observation, a greater depth of understanding about specific elements of these competitions is needed to guide contest development. In this way appropriate levels of "real-world" interaction can be implemented to balance the offering of classroom-based education for a well-rounded learning experience.

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