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Project-based Sustainability Courses Provide Practical Educational Experience for Students while Advancing Sustainability within the Local Community

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Project-based sustainability courses provide practical educational experience for students while advancing sustainability within the local community

Abstract
The implementation of project based learning and subsequent collaborations between the University, local utilities and area businesses, originally aimed at giving senior level engineering students experience in real world problem solving within the area of sustainability have resulted in a successful model for community engagement. Sustainable Energy Systems, taught in the Mechanical Engineering (ME) Department, focuses on renewable energy technologies, such as photovoltaics, wind energy and solar thermal systems. Sustainable Design and Construction, taught in the Civil Engineering (CE) Department, considers the environmental, economic and societal impacts of sustainable materials, methods and technologies used in building construction. Semester-long projects involved pairing student groups from each class with a local business interested in incorporating sustainable technologies into their organization. Teams from the ME department focused primarily on feasibility studies for solar thermal, solar PV and other heat reclamation technologies. Teams from the CE department analyzed existing buildings for the potential of earning green construction and design certifications and made recommendations for the implementation of other energy and material saving technologies. Each project involved meetings with the owners, a site visit, energy assessment by the local electric utility and required the students to hone their professional communication skills. These projects represent a unique opportunity to provide a practical educational experience for students while advancing sustainability within the community. At the close of the semester, one company moved forward with their project, and actually installed a solar thermal system.

Introduction

This paper describes the implementation of project based learning into two sustainability-themed classes in the Mechanical Engineering and Civil Engineering departments with the goal of giving senior level engineering students experience in real world problem solving within the area of sustainability. Sustainable Energy Systems is an upper division advanced technical elective offered to mechanical and chemical engineering students. The course historically included an overview of the following sustainable energy technologies: solar thermal and solar photovoltaics, wind energy, geothermal, fuel cells, solar stirling engines and nuclear energy. Sustainable Design and Construction is a senior level technical elective in the Civil Engineering department. The course was originally designed as an introductory course to sustainable building design and construction practices and followed the LEED (Leadership in Energy and Environmental Design) guidelines with the goal of preparing students to take the LEED Green Associate exam following the end of the course.

Prior to the Spring of 2014, both of the courses mentioned were primarily lecture based and included weekly homework, exams and final projects exploring a technology of choice by the students. Since the course content included so many different topics and technologies, a technically intensive, in-depth look at each technology was not feasible. This resulted in the class seeming technically shallow and not very intellectually challenging. To address these issues and in an effort to increase active learning and the development of student professional skills, the

courses have transformed to a project-based format with traditional lectures and guest lectures covering the original content sprinkled in.

Teams of students were paired with local business owners interested in conducting feasibility studies focused on increasing the energy efficiency of their organization and implementing renewable energy technologies. Throughout the semester, each team completed an energy audit with their businesses, gave several professional presentations to their business owners and completed final reports that included a recommendation for moving forward based both on the technical understanding and an economic analysis of the proposed system. Through these collaborations, strong partnerships were developed with a local nonprofit focused on energy efficiency and community resiliency, the local city government, local electric utility and local businesses in the area. It became evident through this successful collaboration that developing these partnerships between the university and the community can have a great impact on advancing the knowledge and implementation of sustainable measures within the community.

This paper summarizes the known benefits of project-based learning, the role of community collaboration, an overview of the timeline and milestones for the semester-long projects, a couple of examples of projects and a list of lessons learned.

Background

Motivation for the implementation of these semester-long projects came from a desire to provide students with real-world experiences in problem solving and a place for them to develop and hone their professional skills. It is commonly known by anyone that has ever stood in front of a class, that bored students do not learn as well as engaged students[1]. It has been shown that project based learning promotes buy-in from students and helps them to feel engaged in the material they are learning[2]. A project based learning environment provides students with the opportunity to explore and investigate problems and scenarios similar to those they will find after graduation.

Project based learning in one form or another has been around for many years. In 1959, John Dewey came out with one of the first formal articles discussing project-based learning. In it he explained how he taught students in his laboratory through a process of inquiry, where he gave them real-world scenarios and problems to solve. When the students felt engaged and invested in a real, legitimate project, Dewey observed that the students gained greater understanding of the material[3]. Today it is commonly accepted that project based learning environments possess five main components: a driving question, exploration of the driving question through authentic, situated inquiry, a community of collaboration that includes students, teachers and community members aimed at engaging the students, scaffolding of concepts that are outside of what they already know, and a tangible outcome directly related to the original driving question[1].

Coming up with projects that not only include the five components listed above but also interest the students and make them excited to learn and participate over the course of an entire semester can be difficult. Projects centered around sustainability themes usually track well in terms of gaining and keeping students' attention[4-6] and many educators around the globe have had success with incorporating project-based learning into engineering courses focused on sustainability[7,8]. Students learn what drives sustainable changes to happen, how these changes happen, and about the important role that they can and will play as they enter the professional world and become

members of a community. The level of engagement observed in the students during the semester-long projects in the Spring of 2014 was a testament to the power of project-based learning.

One somewhat unexpected outcome of incorporating these projects into the sustainability courses was the development of a strong relationship between the University and the community and the realization of the power such a collaboration has in moving sustainability forward on a city-wide scale. The city is quickly becoming a leader in the area of sustainability and resiliency. The city is currently competing for $5M in a national contest called the Georgetown Energy Competition, which aims at reducing electrical and natural gas use within the city over the next two years. A Department of Energy (DOE) grant was also recently awarded to facilitate the installation of the first MW of solar photovoltaics in the community. In 2017, the District Heating Plant in downtown will be converted from an inefficient steam system to hot water. Along with these efforts by the city, the local sanitary district is making great strides toward becoming more sustainable through the installation of biogas digesters, with future plans for a combined heat and power system on site.

The University has also been heavily involved in the sustainability movement and has been actively pursuing sustainability goals for some time. The Chancellor has demonstrated their commitment to energy sustainability through the development of Campus Goal 6 of the Strategic Plan, which challenges the university to "utilize the University's infrastructure; technologies; and information, human and financial resources to support the campus in a sustainable manner." In 2008, the University signed on to the President's Climate Commitment to reduce greenhouse gases by 25% by 2020; so far the University has maintained a constant carbon footprint, which is impressive when considering that campus square footage has increased by 40% since that time. Solar photovoltaics, small wind and LEED certified buildings have already been installed in an attempt to decrease our carbon footprint. Furthermore, efforts are continuing through the development of two campus-wide Sustainability Committees directed around Operations and Education. In order for the University to reach the Climate Commitment goal and contribute to the energy transition the City is currently undergoing, it is necessary to look outside the University and collaborate with the community. With all that is happening in the community, there has never been a better time for the University to join in this movement and contribute to the rapid transition that is occurring in the city toward a more sustainable future[9].

Community Collaboration

The success of these projects was made possible through close collaboration with many individuals and organizations within the community. The key players are listed below.

Local Nonprofit is a nonprofit organization working on energy efficiency and resiliency within the City. The CEO of the nonprofit was an invaluable partner in these sustainability projects and served as a communication hub for getting area businesses on board, as well as the local utilities, the city and others. Creating the partnership with the nonprofit was invaluable for making connections with the businesses and clients involved in the projects. They already had strong relationships with the participating businesses, city and local utilities. They were the ones to initially reach out to the businesses to gauge interest in participating in these projects.

Local Utility, proved to be a key collaborator as well and provided each student team and corresponding business with a free, donated commercial energy audit. This allowed the students

to experience how an energy audit works and provided the businesses with useful energy information for their organization. Since these projects and the positive feedback from the businesses, the local utility has adopted a new policy where any commercial organization in the city can get a free energy audit.

Six local business owners participated in the 17 projects, meaning that all of the owners had between 2-4 teams working with them over the course of the semester. All of the businesses involved volunteered their time to participate in these projects. A brief summary of each is as follows:

- Local Brewing Company 1 is not even five years old but is already seeing tremendous growth and popularity in the region. Sustainability is a large part of the owner's' vision for their company; students investigated solar photovoltaics and solar thermal systems and possible LEED O+M certification of a recently acquired expansion property.
- Local Brewing Company 2 is the city's oldest microbrewery. The owner was interested in energy efficiency measures that could be incorporated into the existing facility and investigation of a new refrigerator system.
- Local restaurant is a local favorite that prides itself on using fresh, local, organic ingredients. The owner was kind enough to take on four teams investigating: energy recovery technology in the kitchen, solar photovoltaics or solar thermal to help run a hoop house where produce, fish and rabbits are raised year round, and possible LEED O+M certification in a new restaurant that is currently under renovation.
- Local bank has been serving the people of the area for over 80 years. The owner expressed interest in learning about and possibly installing photovoltaics on one of the branch offices, with a plan to provide financing for other local organizations interested in pursuing renewable energy technology.
- Local manufacturer is a local company that manufactures wax canvas bags for outdoor adventures. The owner was interested in investigating the installation of solar photovoltaics with the goal of powering all of the sewing machines with energy from the sun. They were also interested in learning about the possibility of LEED O+M certification for an adjoining office space they had recently acquired.
- A community solar garden is currently being considered for a section of city-owned land that would offer both a good space for energy production and a place for the community to gather and learn about renewable technology. The project is in the early planning phases and student teams were asked to come up with site layouts and potential solar PV systems that could serve both of these purposes.

Project Scopes, Timelines and Milestones

The projects varied considerably in content from owner to owner and even those within the same organization varied as well. The goal from the beginning was to maintain an open-endedness to the projects, motivating the students to problem solve, think outside the box and to learn how to listen to their clients and consider their changing needs and questions throughout the process. Engineering students are regularly given projects in other classes, but these are usually very prescriptive and require following specific methods to complete. By leaving the projects open ended, this allowed the students to utilize their creativity and problem solving skills more than usual, and by giving control of the project to the clients, a more real like experience was achieved.

From start to finish, the projects lasted approximately 15 weeks. At the start of the semester, a meeting was held between the professors and each of the business owners where expectations of both the students and the owners were discussed and a general scope of each project was developed based on the owner's interests and needs. Each project was identified as either a mechanical or civil-based project. The students were presented with an overview of each project and then asked to submit a professional business letter explaining their top choices and what role they would best play in a team (leader, engineer, communications, etc.) and their resume. Using these letters of top choices, the teams were constructed of four to five students per project.

Once the students were assigned to their teams, an evening Kick Off Party where all of the business owners and students could meet and mingle was planned and executed. The students were asked to prepare a memo that included a formal introduction of their team to the owners as well as a list of preliminary questions and data that would be needed for the project. The Kick Off Party was a big success and was attended by all of the business owners, the upper administration at the university, the local utilities and the local media. Appetizers and drinks were provided by the businesses focused in that area and the students all dressed up. The event was very useful in setting a professional tone for the remainder of the semester.

Over the following several weeks, the students were asked to schedule a site visit and energy audit with the local utility for their business. During this time, the students also worked at investigating literature on possible technologies and strategies relevant to their business and looking up case studies that could be helpful in addressing the topics the owners had indicated interest in.

At the midterm, the students compiled all the background research and case studies as well as three options for moving forward and a recommendation into a midterm report and presented their findings to the owners in a professional presentation. The clients were asked to give feedback on the options and recommendation and to direct the students in the direction that best met their needs for the remainder of the semester.

The second half of the semester was spent working on the technical design or plans and an economic analysis of the option selected. Throughout the semester, guest lecturers relevant to the projects were brought in. During this time, the speakers were especially helpful when it came to the economic analysis as students were asked to calculate payback, consider state and federal incentive programs, etc.

At the close of the semester, the students amassed everything they had done in a final report that was given to the owners along with another presentation of the technical design and economic analysis. The students were also asked to create a poster summarizing the entire project. The posters were presented at a Final Party where university administration, the students and business owners were all invited. The cost of the venue as well as food and drink were provided through donations from the local nonprofit and some of the businesses. The poster presentations were well received.

Project Examples

In total there were 17 projects that took place during the spring semester of 2015. In the following sections three projects are highlighted that represent the depth and variety of the

projects. As stated previously, most of the projects began without a strictly defined project scope. In most cases the students began by gathering information, such as the owner's goals, the utility constraints of the company (i.e. did they own their own building, pay for their own electricity, etc.) and the processes involved in the company, in order to develop their energy efficiency or renewable energy technology design suggestions.

Local Restaurant: Solar Thermal System

The local restaurant is a privately owned eatery that focuses on locally and organically grown, farm-to-table food. They grow some of the food they serve in the parking lot as well as in the owner's backyard. The local restaurant participated in four different student projects including solar thermal heating, energy recovery, LEED certification, and feasibility of solar photovoltaics. The two projects that will be highlighted here are the solar thermal and heat recovery projects.

Figure 1: The 5,000-gallon fish tank located in a hoop house for the purpose of raising fish for the restaurant.

The local restaurant utilizes not only space in their parking lots but also the owner's front and backyards for growing food in their restaurant. In addition, they have a hoop house that they heat during the winter months for growing food with future plans to also raise fish. In order to raise the fish, they have built a 5,000-gallon fish tank into the ground that is positioned inside of the hoop house. The fish tank in the hoop house is shown in Figure 1. The local restaurant wanted to raise pacu fish, which need to be in water between 70-90 degrees Fahrenheit. When the project began, the owners were paying approximately $1,000 per month to heat the hoop house and expressed interest in finding ways to reduce their electric bills. They were initially thinking of solar photovoltaics; however, the students were quick to identify the increased potential benefits of adding extra insulation on the northern side of the hoop house and a solar thermal heating system.

A solar thermal system was available from the professor's lab that was not currently in use and the students were so engaged in the project that they took the initiative to install the system themselves even though this was not required of them for class. They worked long hours alongside employees from the restaurant to dig the trenches for the pipes, install the hot water heater, heat dump and control system. Figure 2 shows the installed solar thermal system after completion. During this past winter the owner has reported that his electric bill has been reduced significantly by the system.

Figure 2: Hoop house with installed solar thermal heat pipe system.

Local Restaurant: Heat Recovery System

A second project with the restaurant involved potential heat recovery from their cooktops to be used to heat parts of the restaurant that customers had complained were cold. A company had approached the restaurant with an idea to install heat recovery systems along the backside of the grill just a few inches above the cook surface. The company explained that the heat recovered from the grill could be used for heating in places where patrons were cold. They quoted the system to be around $30,000. The restaurant owner wanted the students to vet the technology and help him decide if the cost was appropriate.

The students began with a case study review to see if other restaurants were utilizing this technology and experiencing the same benefits the company advertised. The students quickly found that these systems often lost their efficiencies quickly due to reduced heat transfer as a result of the ducts being coated in cooking grease. The systems were also difficult to get clean to fix the problem. In most cases these systems were no longer in use. Through their searches of other potential heat recovery equipment the students found a desuperheater that could be attached to the vapor compression cycles of a freezer. A desuperheater reclaims some of the heat that would otherwise be rejected to the environment and used for other purposes. In the case of the restaurant, after visiting and seeing how the kitchen operated, the students were able to identify preheating dishwasher water as a good place to use the reclaimed heat energy. Through their calculations the students found that 90% of the dishwashing water could be preheated to 100 degrees Fahrenheit using the reclaimed heat from the desuperheater. They also calculated that the system would pay back in just under two years.

Local Brewing Company: Brewing Efficiency

The local brewing company started in 1994, specializing in craft beers. They boast at being the first microbrewery in the state and have won several awards for their beers. In recent years they have seen increased growth as demand for their beer rises. They began the semester by wanting the students to look at relocating their cooler from inside to outside in order to free up additional space in their brewing area as well as to take advantage of the cold winter months and reduce their cost for cooling their beer. The students quickly found out however, that the brewing company had some unique challenges that they had to work around. For instance, the brewery does not own the building, nor do they pay for their electricity. However, they do pay for natural gas for heating. In addition, they were contemplating a move to a new space that they would own. One of the teams focused on designing them a new cooling space that could either be built at their current location if they chose to stay or built at a new location. The other team looked at energy saving measures that would help them improve the efficiency of their current operations with a special focus on heating.

Figure 3: Owner-led brewery tour for students.

The team focused on saving the brewery energy in heating quickly focused in on two places that lost or gained a lot of heat, the overhead door to the outside and the doors to the walk in cooler area, as shown in Figure 4a. The microbrewery is located in one large space, where the sampling room, the brewery and the delivery area are all open to each other. The brewery typically receives or sends out one to two shipments per day. In the middle of the winter this means a lot of heat is lost when the overhead door is up. In addition the entry to the cooler is passed through several times day. Originally there were plastic strips hanging in the doorway to the cooler to mitigate heat gain, however due to their nuisance and inability to pass through with a forklift when in place, these have been permanently moved out of the way. Through searching for options to help save energy when these doors are open, the students came across blower doors that create a blanket of air between the inside and outside, as shown in Fig. 4b. These air curtains help mitigate drafty air from entering or leaving through the doorway. The owners were very happy with the students' findings.

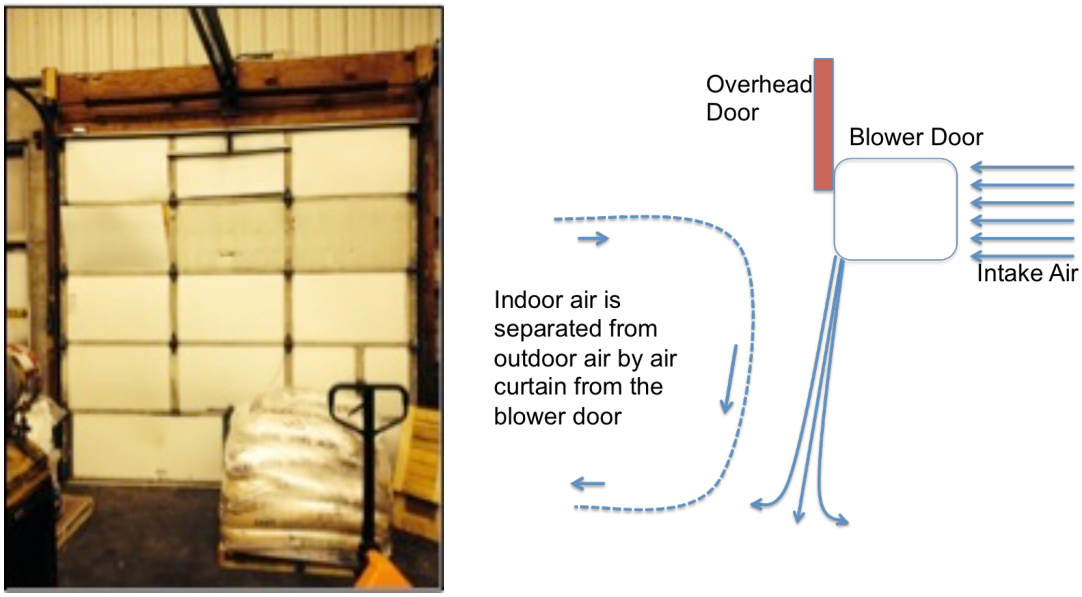

Figure 4: a) Overhead door in brewery, b) Air curtain airflow barrier between indoor and outdoor air.

Lessons Learned

As this was the first time these projects were implemented in the sustainability classes, there were a lot of lessons learned. A few key lessons are listed below:

- *Limit number of students and teams:* 17 teams were too many teams to keep track of and give prompt and in depth feedback to on a daily basis.
- *Allow more contact between owners and students:* Initially, there was some concern that the students would contact the clients too much and become bothersome, however in speaking at the end of the semester, both students and clients expressed that more contact would have been useful. And as these are open-ended projects, the more guidance the clients can give the better the student solutions will be.
- *Involve the public more*: The final projects and posters would have offered a great opportunity to invite and educate the community on what is going on at the university and offer the opportunity to learn about renewable energy and energy efficiency and what is going on in the community in terms of sustainability.
- *Work with writing studies:* Throughout the semester, it became clear that the students needed formal instruction on professional communication, both written and oral. The Writing Studies department was invited to give two lectures on audience and references, however, in the future there will be more formal incorporation and instruction to help the students grow these skills.
- *Provide detailed rubrics and checklists:* The purpose of assignments was not always fully understood by the students, and so by providing more in depth assignments and explanations of why each assignment is important, the students will become more engaged in the work. In addition, as stated earlier, it was difficult to provide timely and in-depth feedback on 17 projects; using rubrics and checklists will help.

Student Learning Outcomes

Based on feedback and experiences from the first semester of implementing these semester-long projects, student learning outcomes have been developed that will be used in the next semester. Each assignment given over the course of the semester long project will have a learning objective associated with it that will lead directly to one of the outcomes of the project. The objective is listed at the top of each assignment so that the students can see the value of the work being asked of them right away. Some examples of these learning outcomes are shown below:

- Assignment: Cover letter describing the projects you would most like to work on.
  The *objective* of this assignment is to practice writing professionally and present yourself in a professional manner. In addition, this assignment allows you to have some influence on what your project will be for the semester.
  Associated learning outcome: Students will be able to write professionally.

- Assignment: Memo summarizing the scope of the project, information needed and background.
  The *objective* of this assignment is to think critically and make engineering decisions regarding the scope of the project, data needed from owner to make appropriate calculations and to present the background for a project in a professional manner.
  Associated learning outcome: Students will be able to make decisions appropriate to the engineering discipline.
  Associated learning outcome: Students will be able to make presentations that communicate clearly technical content.

- Assignment: Summary of relevant case studies
  The *objective* for this assignment is identify and make engineering decisions about what projects in the literature make good examples or comparisons to your project. Learn what has already been done and what lessons can be learned. In addition, this assignment will help you to become more familiar with the technology involved in your project.
  Associated learning outcome: Students will be able to research engineering projects and transfer appropriate information and apply it to existing projects.

Conclusion

Two senior level engineering courses combined to incorporate project-based-learning into the courses. The projects resulted in collaboration between the University, local electrical supplier and area businesses. The goals of the project were to provide engineering students with experience in real world problem solving within the area of sustainability. These projects resulted in a successful model for the University to act as a change agent in the community. The semester-long projects involved pairing student groups from each class with a local business interested in incorporating sustainable technologies into their organization. The projects ranged from feasibility studies for solar thermal, solar PV and other heat reclamation technologies to LEED analyses of existing buildings. The projects allowed for students to interact with their client several times throughout the semester, providing them with multiple opportunities to practice their professional skills. These projects represent a unique opportunity to provide a practical educational experience for students while advancing sustainability within the community. At the close of the semester, one company moved forward with their project, installing a solar thermal system.

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