AC 2011-45: TEACHING ENERGY EFFICIENCY FUNDAMENTALS IN CONSTRUCTION EDUCATION: PROJECT REDUCE

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Teaching Energy Efficiency Fundamentals in Construction Education: Project REDUCE

Abstract

In recent years, energy efficiency has resurfaced as an important topic in construction education. Finding the appropriate location in the curriculum can be a challenge for construction educators as other topics prevail through requirements previously set forth by accreditations review boards. To increase knowledge of energy efficiency fundamentals, the Reduction in Energy Demand and Utility Consumption Evaluation (REDUCE) project was developed as part of a specialty contracting construction management course. The project-based learning effort requires student teams to identify a building that is in need of energy efficiency improvements. Student teams then conduct an energy audit for the building, identify projects that will result in reducing energy demand and utility consumption, prepare a cost estimate to perform the work, and calculate the project financial feasibility for the proposed projects. This paper demonstrates how Project REDUCE can be used to teach students about energy efficient fundamentals at the same time as provide them with a hands on experience. In addition, the paper will cover the teaching methodology used, project milestones scheduled to motivate students, and the criteria used to assess student learning.

Introduction and Background

A new curriculum recently adopted at California Polytechnic State University, San Luis Obispo (Cal Poly) is based on a model similar to that proposed by Hauck and Jackson[5], where construction management is taught as a series of labs integrating the various construction management courses into an active, applied learning experience. The integrated curriculum for the Cal Poly construction management department centers on seven (7) project-based laboratory courses. They are as follows:

- Fundamentals of Construction Management
- Heavy Civil Construction Management
- Residential Construction Management
- Commercial Building Construction Management
- Specialty Contracting Construction Management
- Construction Jobsite Management
- Interdisciplinary Project Management

Students receive six (6) quarter-hours of lab credit for a total of sixteen (16) contact hours per week. Similar to a studio in an architecture curriculum, each laboratory is taught in a dedicated space furnished with models, samples, contracts, marketing documents, specifications, estimating guides, computer references, and other tools appropriate to that in the construction industry sector, all available to students in that seminar.

The concept for the specialty contracting construction management course was to emphasize the work of specialty contractors who fabricate and install mechanical, electrical, and plumbing (MEP) systems; whose work is characterized, by most construction industry professionals, as being specialized and requiring a considerable amount of technical knowledge required for fabrication and installation of the systems. Originally, the course curriculum was developed on the basis of integrating the course content from a mechanical systems course and an electrical systems course, which existed in the prior curriculum. As noted above, the integrated curriculum model described by Hauck and Jackson[5] has the potential to provide tremendous opportunities to engage teaching strategies beyond the common lecture approach typically utilized in many single subject courses. Various methodologies such as cooperative learning require students to be active participants in their own education[2]. Therefore, to take advantage of the studio-laboratory format and to increase knowledge of energy efficiency fundamentals, the Reduction in Energy Demand and Utility Consumption Exercise (REDUCE) was developed as part of a specialty contracting construction management course. The following sections describe the design of laboratory exercise, including the learning objectives and outcomes assessments.

Energy Efficiency Fundamentals

MEP systems are the active systems of a building, whose purpose is to temper the building environment, distribute electric energy, allow communication, enable critical manufacturing process, provide water and dispose of waste[7], etc. MEP systems have increased in scope on many types of projects, due to the increased requirements by building users. With the need for increased functionality of these systems, projects now include much more than the traditional MEP systems. The active systems of a building can cost up to 60 percent of the total building cost[7] and their scope now includes additional systems such as fire detection/protection, controls, process piping, and telephone/datacom. In recent years, energy efficiency has resurfaced as an important topic in construction education.

According to the United States Department of Energy, traditional building use consumes 40% of the total fossil energy in the US. The REDUCE project was developed to increase awareness to energy efficiency fundamentals and to provide students with an opportunity to "learn by doing" experience. The project-based learning effort requires student teams to identify a building in which energy demand and utility consumption can be reduced. Student teams then conduct a facility energy audit for the building, identity projects to save energy, prepare a cost estimate to perform the work, and calculate the project financial feasibility of the proposed projects. The teaching methodology used, project milestones scheduled to motivate students, and the criteria used to assess of student learning for the project is described below.

Reduction in Energy Demand and Utility Consumption Evaluation (REDUCE) Project

Teams are required to identify a building in the vicinity campus who will then become their "client". Acceptable projects include any building (except residential) that is off-campus and greater than 5,000 SF. Once the student team identifies a building, the teams conduct an energy audit for the building, identifies projects that will reduce energy demand and utility consumption, prepare a cost estimate to perform the work, and evaluate by the financial feasibility by calculating the benefit to cost ratio and the pay back period of the proposed projects. Teams then prepare a written proposal and present their findings to the class.

The REDUCE project is considered a service learning project, the students are expected and encouraged to gain input and feedback on their proposal from contractors, vendors, and materials suppliers; however, students are not permitted to earn wages for participation on the project. Student teams are expected to conduct themselves in a professional manner in all aspects of the project. Student teams are expected to plan visits and phone calls with clients in a professional manner that is not disruptive to the activities of the client. To motivate students to keep on task, the following milestones are required for throughout the project:

- Milestone No. 1 - Project Identification and Summary of Qualifications
- Milestone No. 2 - Site Assessment Forms (including Site Layout and Building Elevations)
- Milestone No. 3 - One-Line Drawings and Technical Analysis Progress Update Report
- Milestone No. 4 – Technical Analysis Report

Project REDUCE: Learning Objectives

The REDUCE project was designed to expose students to the detailed knowledge of energy efficiency analysis and reduction techniques. Because, the specialty contracting construction management course is an upper division class within the curriculum, the approach taken was to have the students study and report on the existing system as well as analyze and make recommendations for improvements of the systems that would result in a net energy consumption decrease by the building. Therefore, the project was developed with the following learning objectives:

- Describe and analyze the existing building systems through producing diagrammatic drawings for each system
- Discuss and report on the opportunities to reduce energy demand and utility consumption for the following building systems: potable water, landscape irrigation, lighting, and natural gas
- Analyze the building envelop and propose improvements to the HVAC systems that would reduce energy demand and utility consumption while at a minimum maintaining existing comfort levels and even more desirable enhance comfort for building occupants
- Identify an opportunity to incorporate on-site energy production via solar photovoltaic systems and/or wind energy production
- Estimate the cost and savings (from energy and utility) for each proposed project and evaluate the cost savings in energy consumption for each proposed improvement

Project REDUCE: Student Task

Students begin the project by completing a general information sheet for the building they selected. This includes information regarding the location, and primary use of the building name, address, phone number, and e-mail of the building contact. Students are also asked to create a summary of qualifications for their team, which is basically their current resume.

Students begin the project by conducting a site visit and assessing of the existing conditions of each system. Evaluation forms are provided to each student team to assist them with this task. We encourage them to include images, sketches, photos, etc. and produce one-line drawings of existing conditions of the buildings systems. We reinforce to the students that one-line drawings are not always available from the client; therefore the team may need to create them prior to beginning their systems analysis.

The energy audits are performed using the worksheets provided during the course lectures on energy auditing. These worksheets provide the basic data-gathering tool for performing an energy audit. We recommend the following:

1. Water, electricity, and natural gas usage records for the facility; records for the previous fifteen (15) months are preferred.
2. Facility drawings showing details of electrical and mechanical systems as well as building construction details. There are used to determine the extent of systems and level of building envelope insulating value.
3. Interviews of facility maintenance staff to determine age and general condition of the facility and its systems. This usually gives the team an idea if any major systems or facility upgrades are planned or have been recently completed.

Teams are then expected to evaluate and analyze each the system. A brief description of each analysis is listed below.

Potable water - Teams are expected to assess and make recommendations to reduce the use potable water in the facility based on criteria they feel is appropriate for the client. Improvements may include partial or complete replacement of water supply system, plumbing fixtures, etc. One-line diagrams of the existing and proposed design are required. Students are asked to include impacts on the water supply system and water use calculations including the benefit to cost ratio for each proposed improvement.

Landscape irrigation and landscaping - Teams are expected to assess and make recommendations for a more efficient use of water for landscaping based on criteria they feel is appropriate for the client. Improvements may include partial or complete replacement of landscaping, sprinkler system, control systems, installation of a gray water system, installation of a rainwater harvesting system, etc. A site plan of the existing and proposed design are required. Students are asked to include impacts on the landscape irrigation system and water use calculations including the benefit to cost ratio for each proposed improvement.

Electrical lighting - Teams are expected to assess and make recommendations for a more efficient/green lighting system based on criteria they feel is appropriate for the client. Improvements may include partial or complete replacement of fixtures, lamps, ballast, and controls. Reflected ceiling plans of existing and proposed design are required. Students are asked to include impacts on day lighting and energy use in calculations and to calculate the benefit to cost ratio for each proposed improvement.

Building envelope and HVAC System - Teams are expected to assess and make recommendations to improve the buildings envelope and heating, ventilation, and air-conditioning (HVAC) system based on criteria they feel is appropriate for the client. Improvements to the building envelop may include partial or complete replacement of windows, window awnings, and roof system, increasing the resistance value. Cross sections of existing and proposed improvements to building envelope elements (wall, roof, windows, etc,) are required. Improvements for the HVAC system may include partial or complete replacement of HVAC equipment, including fans, pumps, duct insulation, etc. A one-line diagram of the existing and proposed design is required. Students are asked to consider impacts on solar heat gain, day lighting, new equipment and energy use and calculate the benefit to cost ratio for each proposed improvement.

Natural gas - Teams are expected to assess and make recommendations for a more efficient use of natural gas in the building based on criteria they feel is appropriate for the client. Improvements may include partial or complete replacement of hot water heating system, installation of solar hot water heating system, replacement of gas using equipment, etc. One-line diagrams of the existing and proposed design are required. Students are asked to include impacts on the gas distribution supply system and gas use and calculate the benefit to cost ratio for each proposed improvement.

Electrical distribution system and on-site electricity generation – Teams are expected to identity at least one aspect of the building electrical systems and make recommendations for potential improvements. Suggested areas for improvements include: transformer replacements, service upgrades in computer laboratories, and distribution systems retrofits. We encourage them to focus first on identifying particular problems already identified by the client, for example problematic areas in the current electrical service and areas of excessive power use. In addition, teams are expected to identify an opportunity to incorporate on-site energy production via solar photovoltaic systems and/or wind energy production on the building. Also required is a general assessment of the advantages and disadvantages of options, and a schematic design of the PV/wind system and cost estimate using actual price quotes for system components.

Project REDUCE: Assessment of Student Learning

Upon completion of all project task, the teams are encouraged to solicit a letter from their client summarizing the performance of the team and the client's comments on the proposed improvements. The letter is expected to be included in the appendix of a written proposal submitted with the final report. In addition, we e-mail an evaluation to the teams' client to obtain feedback of their professionalism and the client's satisfaction with the students work.

Teams are allowed 25 minutes to make an oral presentation that communicates the highlights of their project. Each team member is expected to participate. At the conclusion of the presentation, a 5-minute question and answer session commences, where all other students are allowed to ask questions. Once teams have completed their question and answer session, they are expected to rejoin the class for the remaining presentations.

Discussion and Recommendations for Future Implementations

Integrating the course content of energy efficiency fundamentals for construction management students is one approach to help encourage students' interest of MEP and their affect on sustainability. Compared to students who have been taught via the traditional lecture mode, the cooperative environment provided a forum in which a deeper understanding of the material could take place and motivation could be placed on learning and achieving a common goal[3].

The REDUCE project encompasses many of the seven principles of good practice for education by encouraging contact between students and faculty, developing reciprocity and cooperation among students, encouraging active learning, giving prompt feedback, and respecting diverse talents and ways of learning. It allows an enhanced level of student-faculty contact by allowing the students and faculty to work together in a fashion other than the traditional lecturer-listener relationship that is most commonly found. It encouraged students to work with their peers and the faculty member to achieve the above listed learning outcomes. It also encouraged active learning by experimentation and gave students prompt feedback. It also allows students to learn in a multitude of ways by allowing students of all learning styles to develop from the experience. From our observations kinesthetic learners benefit from the data collection task, visual learners benefit from being able to visit the actual sites, and auditory learners benefited from working in student groups by either giving or receiving instructions.

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