# INTEGRATING SUSTAINABILITY CONCEPTS INTO CONSTRUCTION ENGINEERING EDUCATION THROUGH SERVICE LEARNING PROJECTS

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**Abstract:** In recent years, sustainability has surfaced as an important topic in society and therefore has become a goal of many construction engineering faculty to incorporate sustainability topics into their curricula. Determining an appropriate location in a curriculum can be challenging for educators as they frequently already struggle to schedule topics required by accreditations review boards. In the effort to introduce construction engineering students to sustainability concepts, the author has developed and implemented a variety of project based service learning projects aimed at integrating sustainability into an existing curriculum. These include the Reduction in Energy Demand and Utility Consumption Exercise (REDUCE) project, the Building Information Modeling for Energy Efficiency (BIM-E$^2$) project, and the Renewable Energy for Central America (RECA) project. An abundant amount of existing research concludes that service learning enhances a student's education in the areas of: work ethic, critical thinking, problem solving, social issues, and reasoning. This paper outlines the development, implementation, and evaluation of the aforementioned projects and how they are used to teach sustainability concepts while at the same time providing them with hands-on experience in a service learning pedagogy.

## 1 INTRODUCTION

Sustainability has become an important topic in construction education and therefore has become a goal of many construction engineering faculty to incorporate sustainability topics into their existing curricula. Determining an appropriate location in a construction engineering curriculum can be challenging for faculty as they already struggle to schedule topics required by accreditations review boards. In the effort to introduce construction engineering students to sustainability concepts, the following service learning projects were developed and implemented with the goal of integrating sustainability concepts into an existing curriculum - the Reduction in Energy Demand and Utility Consumption Exercise (REDUCE) project, the Building Information Modeling for Energy Efficiency (BIM-E$^2$) project, and the Renewable Energy for Central America (RECA) project. These projects were developed for upper division (3rd and 4th year students) construction engineering and management students intended to educate them on the active systems of a building – Mechanical, Electrical, Plumbing, and Fire Protection. The course titled, "Civil Infrastructure and Building Systems" course description reads as follows, "Principles and practices for the sustainable design, fabrication, and installation of systems for the civil infrastructure and building; including structural, air/gas, water/wastewater, electrical, and control systems. Methods and materials used for fabrication and installation; including cost and schedule considerations." The perquisites for the course include thermodynamics, fluid mechanics, basic electric circuit theory, and engineering economics. The prerequisites serve as foundation for the students to study the building systems, and well as be able to think critically about their design and efficiency. In a typical course section offering, student count ranges from 20 to 26 students.

The primary learning pedagogy used to integrate sustainability concepts in the course is project based learning. Project based learning (PBL) is a learner-centered pedagogy in which students explore a subject in the context of complex, multifaceted, and realistic problems. The goals of PBL are to help the students develop flexible knowledge, effective problem solving skills, self-directed learning, effective collaboration skills and intrinsic motivation. Through PBL, students:
Become immersed in open-ended scenarios simulating real-life work situations

- Work in groups, identify what they already know, what they need to know, and how and where to access new information that may lead to resolution of the problem
- Explore a problem or scenario that is presented with missing information and is open-ended allowing for critical thinking and analysis, thus generating a range of solutions that have not been suggested before
- Determine if the problem suggested is the real problem or whether there is a different problem that needs to be solved

The project based learning pedagogy was used within a service learning context. Service learning is a teaching and learning strategy that integrates meaningful community service with instruction and reflection to enrich the learning experience, teach civic responsibility, and strengthen communities. Service learning is a process of involving students in community service activities combined with facilitated means for applying the experience to their academic and personal development. It is a form of experiential education aimed at enhancing and enriching student learning in course material. When compared to other forms of experiential learning like internships and cooperative education, it is similar in that it is student-centered, hands-on and directly applicable to the curriculum.

The critical difference and distinguishing characteristic of service learning is its reciprocal and balanced emphasis on both students learning and addressing real needs in the community. Course learning objectives are linked to meaningful human, safety, educational, and environmental needs that are co-determined with community partners and service recipients. Course materials such as lectures, readings, discussions, and reflection activities supplement the student service. In turn, the service experience is brought back to the classroom to enhance the academic dialogue and student comprehension. Students work on real problems that make academic learning relevant while simultaneously enhancing their social skills, analytical ability, civic and ethical responsibility, self-efficacy, and career development.

## 2 REDUCTION IN ENERGY DEMAND AND UTILITY CONSUMPTION EVALUATION (REDUCE) PROJECT

Mechanical, Electrical, and Plumbing (MEP) systems are considered to be the active systems of a building. Their purpose is to temper the interior building environment, distribute electric energy, allow communication, provide water and dispose of waste, all of which support the functionality and productivity of the building users. According to the United States Department of Energy, buildings consume 40% of the total fossil energy in the United States. Therefore, decreasing the amount of energy consumed by buildings has become a goal of architects, engineers, and constructors. To increase awareness and educate construction engineering students of energy efficiency fundamentals, the REDUCE project was developed to provide students with an opportunity to a service learning “learn by doing” experience.

The REDUCE project was designed as a project-based service learning project which requires student teams to identify a building in which energy demand and utility consumption can be reduced. Students grouped in team of three to four students are required to identify a building in the vicinity campus who will then become their “client”. Acceptable projects include any institutional, commercial, and industrial building 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, identify improvements to the building systems that will reduce energy demand and utility consumption, prepare a cost estimate to perform the work, and evaluate the financial feasibility by calculating the benefit to cost ratio and the payback period of the proposed projects. Teams then prepare a written proposal and present their findings to the class. The

learning objectives, student activities, and criteria used to assess student learning for the project is described below.

### 2.1 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 course is an upper division class, 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
- 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

### 2.2 Project REDUCE: Student Activities

To guide students through the project, the following milestones are required throughout the project: 1) Project Identification, 2) Site Assessment Forms (including Site Layout and Building Elevations), 3) One-Line Drawings and Technical Analysis Progress Update Report, and 4) Technical Analysis Report. 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. They then begin 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. Students are encouraged to include images, sketches, photos, etc. and produce one-line drawings of existing conditions of the buildings systems. Students are reminded 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. Students are then required to perform an energy audit using the worksheets provided to them during the course lectures on energy auditing. These worksheets provide the basic data-gathering tool for performing an energy audit. Finally, the student teams are required to evaluate and analyze each system and prepare a technical analysis report.

### 2.3 Project REDUCE: Assessment of Student Learning

Upon completion of all project tasks, 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. Teams are then allowed twenty-five (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 five (5) minute question and answer session commences, where all other students are allowed to ask questions.

## 3 THE BUILDING INFORMATION MODELING FOR ENERGY EFFICIENCY (BIM-$E^2$) PROJECT

BIM has been defined as the process of creating an intelligent and computable 3-D data set and sharing the data among the various types of professionals within the design and construction team. BIM technology enables architects, engineers, and constructors (AEC) to model and visualize the entire scope of a building project in three-dimensional (3-D) virtual environment as well as to attach schedule and cost data to each component in the model. It has become an ideal tool for assisting and improving project team collaboration. AEC professionals are able to plan-out, in precise detail, the location and clearances needed for a complete and successful project. Realizing the potential BIM technology has to offer, the BIM-$E^2$ project was developed to encourage students to the utilize BIM technology and software for the

purpose of addressing energy efficient issues related to the building envelope. Thus, the focus of the BIM-$E^2$ project is on the building envelope, as opposed to the REDUCE project which focuses on the active system of the building. The premise of the project is for student work groups to use a work process utilizing modeling software and information technology to model an existing building and project energy consumption rates and make recommendations for upgrading the building through the use of the modeling software.

### 3.1 Project BIM-$E^2$: Learning Objectives

The BIM-$E^2$ project was designed to expose students to a work process utilizing BIM software and information technology for the purposes of increasing the energy efficiency of the building envelope. Because the course is an upper division class, the approach taken was to have the students explore the available technology and apply it to a real world project in the form of a service learning project. The students were expected to analyze and make recommendations for improvements of the systems that would result in a net energy consumption decrease by the building. Therefore, the BIM-$E^2$ project was developed with the following learning objectives:

- Analyze the building envelope to determine its existing thermal energy properties
- Propose improvements 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
- Estimate the energy consumption and cost savings for each proposed improvement.
- Calculate the cost and payback period for each proposed improvement.

### 3.2 Project BIM-$E^2$: Student Activities

Students begin the project by modeling the building envelope of an existing building and then are expected to assess and make recommendations to improve the building's envelope based on criteria they feel is appropriate for the client. Improvements to the building envelope may include partial or complete replacement of windows, window awnings, and roof system, increasing the exterior wall thermal resistance value, etc. Use the BIM software, students are expected to model an existing building using BIM software, produce cross sections of existing and proposed improvements to building envelope elements (wall, roof, windows, etc.). In addition, students are required 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.

### 3.3 Project BIM-$E^2$: Assessment of Student Learning

Upon completion of all project tasks, the teams are required to prepare a report summarizing their work. In addition, they 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. Teams are then allowed twenty-five (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 five (5) minute question and answer session commences, where all other students are allowed to ask questions.

## 4 PROJECT THE RENEWABLE ENERGY FOR CENTRAL AMERICA (RECA) PROJECT

The RECA project was designed to encourage students to consider the use of on-site alternative energy production for remote sites in Central America. The premise of the project is to design and install an alternative energy production such as a photovoltaic (PV) system, wind turbine, micro-hydro, etc. to generate electricity for the community. Working in conjunction with the National Electrical Contractors Association (NECA) Cross Border Initiative, sites in Central America are identified where impoverished communities are in need of energy. The sites are located in communities where the community lacks funds to pay for electrical energy upgrades, and in some cases, due to their remote location, are located entirely off the electrical power grid. The partnership formed with NECA Cross Border Imitative has created an industry-university partnership.

### 4.1 Project RECA: Learning Objectives

The RECA project was designed to introduce students to on-site alternative energy production technologies. Because the course is an upper division class, the approach taken was to have the students explore the available technology and apply it to a real world project in the form of a service learning project. The students were expected to analyze and make recommendations for designing, fabricating, and installing the system. The RECA project was designed with the following learning objectives:

- Identify an opportunity to incorporate on-site energy production via solar photovoltaic systems, wind energy production, and/or hydroelectric.
- Estimate the cost for each proposed project and evaluate the cost savings in energy consumption for each proposed improvement.
- Coordinate the procurement, fabrication, and installation of the on-site energy production system.

### 4.2 Project RECA: Student Activities

The RECA project begins with students meeting the NECA industry partners to learn about the site – location, geography, community, etc. The students must then estimate the energy consumption requirements for the project. The students then must research and explore alternatives for generating electricity at the site. Once the students investigate the options, considering cost, transportation, ease of installation, benefit-to-cost, etc., they begin the design process for the system. Students begin with a schematic design and over several weeks, working with NECA industry professionals, select equipment for the design. The students are expected to work with electrical distributors to procure the materials and equipment for the design. Once all materials and major equipment has been obtained, the students assemble the system. They are challenged with the reality that the system must be able to be shipped to the project location for installation. Therefore, they must consider prefabricating as many components and assemblies as possible to ensure an efficient installation. Lastly, the students groups are tasked with developing field work orders for installation to ensure personnel on the receiving end of the systems can assemble and start-up the system.

### 4.3 Project RECA: Assessment of Student Learning

Throughout the project, students were assigned tasks to ensure they kept on pace for completing the project. This became an important aspect of the project where students could realize that their system was intended to benefit a less fortunate group of individuals, and thereby encouraging and motivating them to throughout the project. Much of the learning was done through active participation and observing what the surroundings. A major theme was the comparison and contrast between the U.S. and Costa Rica to better understand construction materials and methods. The teamwork also challenged students to step up and utilize leadership, communication, and coping skills to complete the project in a safe and timely manner. Student reflections from the Costa Rica project indicated that they enjoyed helping the community and interacting with the community.

## 5 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' awareness of their effect on sustainability. This helps to enhance and reinforce learning by arranging content around overlapping concepts and themes. Furthermore, to accomplish the laboratory goals, the students were forced to consider design, construction, and operations and maintenance criteria in order to achieve proper functioning systems. 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 (Bonwell and Eison, 1991).

The projects described above were implemented in a building system course offered to construction engineering and management students, with a typical student count ranging from 20 to 26 students.

Therefore the teaching methodology centered on creating student work groups of three to four. Each of the project described above encompasses two or more 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. In addition, it promotes student learning in a multitude of ways by allowing students of all learning styles to develop from the experience. From 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.

**Acknowledgements**

I would like to thank and acknowledge the College of Architecture and Environmental Design and the Construction Management Department for providing a dedicated lab and classroom space to implement the projects described above. In addition, I would like to thank and acknowledge Hal Johnston, Professor Emeritus of Construction Management at Cal Poly, who encouraged the active learning and lab activities to foster student learning. Finally, I would like to thank the National Electrical Contractors Association Green Energy Challenge which inspired us to develop this project.

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