AC 2011-2277: SERVICE LEARNING IN A MULTI-DISCIPLINARY RENEWABLE ENERGY ENGINEERING COURSE

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Service Learning in a Multi-Disciplinary Renewable Energy Engineering Course

One of the most significant challenges facing this coming generation of engineers is how to fight the complex issues of climate change and increasing energy demands. One solution that is having an increasingly important role is alternative and renewable energy technologies. Emerging applications such as solar cells, wind energy conversion devices, and fuel cells involve significant contributions across a range of traditional engineering disciplines. Therefore, for companies to be successful in researching, designing, and manufacturing these products, they must operate in a truly multi-disciplinary environment. To prepare graduates to be successful in this endeavor, engineering education must provide students with multi-disciplinary learning environments.

San José State University offers a general engineering course on Renewable Energy Engineering. The course is open to juniors, seniors, and graduate students of all engineering majors and is part of the College of Engineering's multi-disciplinary minor in Green Engineering. The course has been offered three times, to date, and typically has students from every engineering major on campus. The class covers a range of renewable energy topics including: how traditional energy is produced, measured, and sold; solar thermal; photovoltaics; wind; hydropower; fuel cells; biofuels; geothermal; and ocean, wave, and tidal energy. In all of the topics, the class covers enough of the engineering fundamentals to allow for mini-design projects in each technology. The classroom periods use an active learning methodology. The classes are structured such that the students work together in multi-disciplinary teams where each student is able to bring the expertise of their major to understanding the technology. For example, the background of mechanical engineers combined with electrical engineers will allow a team to begin to grasp the basic fundamentals of fluid flow and power generation needed to understand how a hydropower plant operates.

A significant assignment in the class is a community-based service learning project done in multi-disciplinary teams. Each team is assigned a renewable energy technology (such as wind power) at the start of the semester. They have a series of assignments designed to give them technical depth in the area and confidence as an "expert" in the technology. Then, the teams design a hands-on teaching demonstration for their technology. They bring this to an after-school program for 4^{th}- 7^{th} graders at a nearby community center. The community center is part of a unique university/ city/ community partnership (CommUniverCity). The service learning project is facilitated by San José State University's Center for Community Learning and Leadership. Assessment of the service learning shows that the project increases students' self reported understanding of the engineering fundamentals, as well as increases their confidence and motivation to make a difference in society.

Need for Renewable Energy Engineering

The burning of fossil fuels and the rapid deforestation of the globe have created an increase in CO_2 gases in the atmosphere and a heating up of the earth's temperature.[1] Data shows an exponential change in CO_2 in the atmosphere in the last several decades.[2] This has been correlated with a warming of the earth's surface temperature.[3] Coupled with the problem of climate change, nations are also struggling with a growing demand for energy alongside a shrinking pool of easily accessible fossil fuel.[4] These challenges are spurring an interest in alternative, renewable energy sources.

Alternative, renewable energy sources include solar thermal; photovoltaics; wind; hydropower; fuel cells; biofuels; geothermal; and ocean, wave, and tidal energy. The alternative energy industry is predicted to grow dramatically in the next two decades, with increasing career opportunities for most engineering majors.[5] These renewable energy technologies depend on an understanding of a broad range of engineering disciplines. Research, development, and manufacturing of these renewable energy devices will require multi-disciplinary teams of engineers.[6]

San José State University's Green Engineering Minor

To be successful in the industry, engineers must have a strong foundation in their engineering discipline, a broad understanding of the complexities facing renewable energy, and an ability to work effectively on multi-disciplinary teams. With these goals in mind, the College of Engineering at San José State University has developed a minor in green engineering.[7] The minor was established in Fall 2008 and is open to all engineering majors. It includes four classes beyond the requirements of the engineering major. Two of the classes are required: Engr 102: Renewable Energy Engineering and Engr 103: Life Cycle Engineering. The student then chooses two classes from a range of other classes including classes on specific engineering aspects (solar energy, wind power) and environmental and policy issues. The requirements for the Green Engineering minor are shown in Table 1.

Table 1: Curriculum for San José State University's Green Engineering minor.

Engr 102: Renewable Energy Engineering
Elective from approved list of engineering courses (such as Solar Energy, Wind Power, Lean Manufacturing, Hazardous Materials)
Elective from approved list of environmental and policy courses (such as Environmental Policy, Energy and the Environment)
Engr 103: Life Cycle Engineering

A cornerstone class of the Green Engineering minor is Engr 102: Renewable Energy Engineering. The class is taught in the General Engineering department and is open to all engineering majors. Students must be at least a junior to take the course, guaranteeing that all students have a foundation in science and engineering fundamentals. This class has been offered three times, starting in Fall 2008. In each semester, all of the engineering majors have been represented and about an equal mix of undergraduate and Master's students.

San José State University's Renewable Energy Engineering Curriculum

The Renewable Energy Engineering course covers a range of renewable energy topics including: how traditional energy is produced, measured, and sold; solar thermal; photovoltaics; wind; hydropower; fuel cells; biofuels; geothermal; and ocean, wave, and tidal energy. The class includes a number of guest speakers and tours that are designed to give students an overview of career opportunities in renewable energy. The 15 week curriculum is shown in Table 2. In each topic, students learn the "big picture" context of each technology including the advantages and disadvantages from societal, environmental, economic, and engineering perspectives. The basic engineering fundamentals are also covered, and students perform an open ended design exercise to optimize the performance of each technology.

Table 2: Topics covered in San José State University's Renewable Energy Engineering course.

Week	Topic
1	Introduction to Renewable Energy
2	Energy Consumption & Sources **Tour of SJSU power plant**
3	Measuring Solar Radiation
4	Solar Thermal **Tour of solar thermal lab**
5	Photovoltaics **Hands on photovoltaic lab**
6	Photovoltaics **Photovoltaic industry guest speaker**
7	Fuel Cell **Fuel cell industry guest speaker**
8	Hydropower **Three Gorges Dam video**
9	Wind Power **High altitude wind guest speaker**
10	Wind Power **Wind turbine guest speaker**
11	Biofuels **Biofuels industry guest speaker**
12	Wave Energy
13	Tidal & Ocean Energy
14	Ocean Thermal Energy Conversion
15	Geothermal **Community Center Project**

The classroom sessions are run in an active learning style; there is no lecturing. Depending on the topic being covered, some engineering majors will have had more of a relevant background of the fundamentals. For each topic, students are divided into multi-disciplinary teams where an emphasis is made to ensure student background on each team is diverse and that each team has members who have the needed functional pre-requisites for comprehending the material. For example, the background of mechanical engineers combined with electrical engineers will allow a team to begin to grasp the basic fundamentals of fluid flow and power generation needed to understand how a hydropower plant operates.

The active learning pedagogy has been shown to increase student engagement and significantly improve learning.[8] For an overview course such as this, traditional lecturing could become a situation where the faculty member lists statistics and engineering fundamentals related to the technology, keeping the information transfer at the low levels of Bloom's taxonomy. The active learning methodology is used to engage the student in the synthesis and analysis levels of Bloom's taxonomy from the initial introduction of a topic.[9] Each class period is structured to engage the students in thinking and reasoning throughout the class period.

Students need to come to class prepared, having read the assigned background material.[10] They then are asked to brainstorm in their teams on the main structure of the technology (main engineering components and the advantages and disadvantages of the technology). The purpose of these initial questions is to place the new material within the context of their current understanding, thus increasing retention.[11] This component of the class challenges the students to think about the technology in a broader perspective, including environmental, societal, and economic constraints as well as engineering challenges.

Following that, students are guided through reviewing and applying the key equations and concepts needed to utilize the technology. The equations and concepts were already covered in the assigned reading. Emphasis is placed on understanding what the real world factors are in the math and how these factors would influence the performance of the technology. The goal of this level of questioning is that students are able to apply the equations and engineering fundamentals to real situations. In placing the material within the context of the technology, students should be engaging in a higher level of learning.[12] In the final stage of the active learning exercise, student teams apply what they have learned to a small, open ended design calculation related to the technology. Table 3 shows the levels of questioning students are guided through in each topic of the course.

Table 3: Schematic of the sections in the active, team based, in class exercise for each renewable energy topic.

Individual Class Preparation: Read assigned textbook chapter before class
Phase 1: **Synthesis** of prior knowledge and **contextualization** of the "big" picture including the environmental, societal, economic, and engineering advantages and disadvantages of the technology
Phase 2: **Application** of calculations and engineering fundamentals to real world examples
Phase 3: Open ended **design** calculation to optimize performance

Throughout the active learning exercise, the faculty member interacts with each group, answering questions and facilitating team interaction. The teams are interrupted intermittently throughout the class period to review the answers, either by having several teams orally report their answers or write them on the board. The solutions to the active learning exercise are always posted on the class site following the class period.

In all of the topics, the classes cover enough of the engineering fundamentals to do mini-design projects in each technology. These are done individually as homework exercises. The design problems reinforce the calculations and engineering fundamentals covered in the class and encourage the students to utilize outside resources such as media articles related to the different technologies. There is an emphasis on building an understanding of the engineering constraints that limit the performance of the technology.

Background on Service Learning Project

A key learning activity in this class is a community-based service learning project. The core part of this assignment is the design of a hands-on experiment related to an assigned renewable energy technology that is targeted to 4^{th}-7^{th} graders. They work in teams to create a unique way of explaining the technology to middle school age children. At the end of the semester, the San José State University students bring their hands-on modules to the Third Street Community Center's after school program. The Third Street Community Center is walking distance to the university campus and services neighborhood children, most of who are from low income families and/or first-generation immigrant families. The renewable energy modules correlate well with the Third Street Community Center's after school program, which has a science and engineering focus.

The students who enroll in the Renewable Energy Engineering class are passionate about making a difference in society through engineering. One purpose of the service learning project is to build on this passion, giving them a tangible way to get involved while they are students. The project fosters an ethic of civic engagement among the engineering students. This engagement with the community should enhance their engagement with learning and increase their dedication to engineering.[13] The positive effects of integrating service-learning in the curriculum include improved retention and graduation rates particularly among underrepresented groups and women, and a stronger civic ethic among students.[14,15,16]

Students, particularly women and underrepresented groups, cite the ability to make a difference in society as one of the main reasons they choose careers in science and engineering.[17] However, the impact engineers have on society is more commonly viewed from a corporate standpoint (for-profit companies develop products and technologies that positively impact society), and thus STEM service-learning has traditionally been integrated from the corporate perspective; e.g. products to benefit society are designed as part of a course. Community-based service learning opportunities offer alternative ways for science and engineering students to become involved and make a difference in their own communities.

This community-based service learning project is facilitated by two organizations on campus: CommUniverCity and the Center for Community Learning and Leadership. CommUniverCity is a model service-learning collaborative that brings together resources of San José State University, the City of San José, and local organizations to address resident identified priorities. The neighborhood involved in CommUniverCity is the Five Wounds/Brookwood Terrace

(FWBT) which borders the San José State University campus. The FWBT neighborhood is one of 19 Strong Neighborhoods Initiative areas identified as distressed by the City of San José State.[18] It is highly diverse: of approximately 20,000 residents, 66% are Hispanic, 15% are Vietnamese, and 9% are of other racial/ethnic backgrounds. CommUniverCity works with faculty to create, support, and enrich service learning projects to address the community development priorities identified by FWBT residents. The service learning project in the Renewable Energy Engineering class directly targets two of the priorities identified by the neighborhood: to create a college going culture and to increase understanding of science and technology.

CommUniverCity provides the community partnerships for the service learning projects on campus. Infrastructure on teaching pedagogy and assessment are provided by the Center for Community Learning and Leadership. This Center assists faculty in aligning the service project with the learning objectives of the class; maximizing learning opportunities; including resident input in the planning, implemention and evaluation of the project; developing outcome measures; and documenting, analyzing and interpreting outcome data.

Renewable Energy Engineering Class Service Learning Project Details

The students go through several milestones throughout the semester for the Renewable Energy service learning project. First, the students are assigned to a renewable energy technology (such as solar cells or wind power). Students are surveyed on their preferences and teams are assigned that balance the student's choice while also diversifying student majors and level (undergraduate/graduate). Next, students individually write an overview of the technology that references at least three media articles. The goal of this assignment is to build in each student an understanding of the "big picture" issues influencing each technology. Then, students individually write a literature review on a very specific research topic related to the technology. The paper must reference at least three technical journal articles on the same research topic. The goal is to build the level of expertise of the student.

The last phase of the project is for the team to come together and synthesize their different areas of expertise to develop a teaching experiment for middle school age children. This activity challenges students to think about what they have learned and explain it in language and concepts that a child can understand. The students discover that it is often hard to explain something in simple terms. While any kind of project could be designed that has students synthesize and apply what they learn, the service learning aspect of the project makes the students feel like their effort in creating the project has value and worth. They have contributed something to society beyond just the abstract learning of the material and the intangible benefit to their future engineering career. Table 4 details the three main steps of the service learning project.

Table 4: Components of the service learning project in a Renewable Energy Engineering class.

Individual Overview: Builds awareness of "big picture" context of the technology
Individual Literature Review: Creates expertise in the technology
Team Design of Teaching Experiment: Synthesizes learning and creates a product that is of value to the community
Utilization of Experiment at Middle School Program: Encourages civic engagement and reinforces learning through teaching of material to others

Assessment of the service learning project was done using a summative survey. Students were asked to self report the impact of the service learning project on their understanding of engineering concepts, motivation to work in the field of renewable energy, and commitment to community service. The students reported their answers on a scale of 1 to 5 [5 being the highest: 5 (Strongly Agree), 4 (Agree), 3 (Neutral), 2 (Disagree), and 1 (Strongly Disagree)].

Table 5 lists the survey questions, the average score, and standard deviation from 22 students in Fall 2010. As can be seen from the data, all of the students strongly felt the service learning project increased their understanding of engineering concepts, their motivation for working in the field, and their interest and confidence in helping society.

Table 5: Results of assessment survey of a Renewable Energy Engineering service learning project. Survey was of 22 students in Fall 2010.

Survey Questions	Average	Standard Deviation
The components of the project (introduction, literature review, and Community Center Project) increased my learning of renewable energy.	4.41	0.59
The project increased my motivation of working in the field of renewable energy in the future.	4.27	0.71
The project increased my interest of using engineering to help society.	4.5	0.6
The project increased my confidence in using engineering to help society.	4.41	0.73
Overall, I enjoyed the project.	4.36	0.66

Summary

The burning of fossil fuels and deforestation of the earth are creating an unprecedented increase of CO_2 in the atmosphere. This is correlated with warming of the earth's atmosphere and climate change. Alongside of this challenge, the coming generation is facing a drastic increase in energy demand with a shrinking supply of accessible fossil fuel reservoirs. These factors are increasing the societal interest in renewable energy engineering.

Research and manufacturing in renewable energy engineering requires a team of engineers from varying disciplines. Each must be trained in the details of their engineering major but have skills to understand the complex societal, environmental, economic, and engineering aspects unique to renewable energy. The engineer should also have experience working on multidisciplinary teams and a motivation to make a difference in society.

San José State University has developed a general engineering class in Renewable Energy Engineering to accomplish these educational goals. The class covers how traditional energy is produced, measured, and sold; solar thermal; photovoltaics; wind; hydropower; fuel cells; biofuels; geothermal; and ocean, wave, and tidal energy. Active in-class exercises are utilized to guide students in building on their prior knowledge, contextualizing the advantages and disadvantages of the technology, applying calculations and engineering fundamentals, and designing solutions.

A major learning exercise in the course is a community-based service learning project where the college students design teaching experiments for middle school children. In the first phase of the project, students individually write an overview of the technology and a literature review. Multi-disciplinary teams of students then synthesize the expertise they gained through these assignments to design a teaching experiment. The teams bring the teaching experiment to a local after-school program for middle school children. Facilitation of this partnership is through CommUniverCity, a model service-learning collaborative that brings together resources of San José State University, the City of San José, and local organizations. Integration of the service learning project into the curriculum is facilitated by San José State University's Center for Community Learning and Leadership. Assessment of the service learning project shows that students find it increases their understanding of engineering concepts and their motivation to make a difference in society.

The next generation of engineers is going to play a key role in helping solve our society's crises including the rising demand for energy and the effects of climate change. Service learning reminds and challenges engineering students that the goal of an engineer is to make a difference in society. Service learning projects allow students to use their enthusiasm now to start making a difference in their community.

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