AC 2008-1329: ROWAN UNIVERSITY'S CLEAN ENERGY PROGRAM

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Rowan University's Clean Energy Program

Abstract

Rowan University has established a clean energy program (CEP). This program utilizes undergraduate students working for credit during the semester, and for pay during the summer months, as well as graduate students – all clean energy interns, to promote energy efficiency and clean energy sources within the state of New Jersey. The CEP has been funded through various sources, allowing equipment, travel, graduate tuition and stipends, as well as summer salary for undergraduate students. Services rendered have included hosting symposia, wind and solar resource evaluation, energy audits, participation in grassroots efforts, as well as website maintenance. The strong belief that this program provides valuable services to the community has led to outstanding efforts on the part of the students.

The clean energy projects have been an excellent way to address many of the ABET A-K criteria. These team-based, multidisciplinary projects have been especially effective at driving home the importance of environmentalism and the need for engineers to be leaders and communicators during policy discussions. The projects also reinforce and expand on core academic subjects through hands-on experience. While homeowners, businesses, farmers, schools and municipalities have benefited from the collective experience of the clean energy program, the participating students, including the lead author on this paper, are preparing for the modern practice of engineering. This paper will present the societal and pedagogical benefits of the project.

Introduction

Rowan University's project-oriented curriculum allows students the opportunity to develop abilities related to the ABET A-K criteria throughout their engineering studies. The hallmark of the curriculum is the Engineering Clinic sequence[1,2], which allow students to apply technical content they learn in class to real-world applications. The clean energy program (CEP), discussed herein, is one of the many opportunities for junior and senior level engineering clinic projects that students are afforded. Through the engineering clinics, paid summer internships, and in some cases graduate studies, students support the goals of the New Jersey Clean Energy Program (NJCEP) and the New Jersey Higher Education Partnership for Sustainability (NJHEPS)

These programs aim to increase and improve the local economy, reduce both the dependence of fossil fuels and imported fuels, reduce greenhouse gas emissions and reduce air contaminant emissions. Rowan University's CEP has been focused on encouraging small-scale changes through awareness and implementation of clean energy and conservation alternatives. The hope is that these grass roots efforts will eventually help facilitate large-scale changes. To this end, students have organized and run Clean Energy Symposia; performed energy audits for small business owners and farmers; erected and maintained 20- and 30-meter-tall wind measurement systems throughout New Jersey; analyzed the resulting wind data and calculated payback periods for various types of wind turbines; and provided technical support and outreach to local residents interested in clean energy technologies via phone and email correspondence.

The purpose of this paper is to describe how the clean energy program fits into the overall scheme of the engineering clinics to provide both an asset to sustainability efforts in New Jersey and educational experiences to the students. Specific aspects of ongoing projects that address various ABET A-K criteria are identified. In particular, these projects teach engineering students about the ethical responsibilities of engineers in regard to environmental consciousness, teach them to promote and enact change in the local community, and prepare them for careers in sustainability.

Project-Based Learning at Rowan University

The engineering clinic sequence is an essential aspect of the Rowan University Engineering curriculum. The engineering clinics were established to help students to develop the so-called "soft skills" identified by the ABET A-K criteria, as well as to apply and reinforce core engineering content in a manner that has meaning to the students. Each semester, students take an Engineering Clinic course. The courses, credit hours and overarching themes for each semester are summarized in Figure 1.

	Fall Semester	**Spring Semester**
Freshman	FEC I (2 CR) Measurements	FEC II (2CR) Reverse engineering
Sophomore	SEC I (4 CR) Design w/ writing	SEC II (4 CR) Design w/ oral communication
Junior	JEC I (2CR) Sponsored research or design	JEC II (2 CR) Sponsored research or design
Senior	SrEC I (2 CR) Sponsored research or design	SrEC II (2 CR) Sponsored research or design

Figure 1. Structure of Engineering Clinic Program

Freshman Engineering Clinic I and II (FEC I & II) serve as an introduction to the profession of Engineering, teaching basic problem solving and other skills that are essential to the study of engineering. In FEC I, students are introduced to metrology, estimation and error analysis. In FEC II, reverse engineering introduces synthesis and design. Teamwork, professionalism, and ethics are emphasized throughout.

Sophomore Engineering Clinic I and II (SEC I & II) focus on design and communication, while continuing to address teamwork and other "soft skills" that are important aspects of the clinic experience. In SEC I, students receive classroom instruction in technical writing while having design laboratories that emphasize parametric design. In SEC II, students receive classroom instruction in public speaking, while having design laboratories that emphasize the framing of design problems. During both semesters, communication instruction is linked to the design project deliverables.

The junior and senior year continues the progression toward more open-ended and more real-world connections for projects. As such, most Junior/Senior engineering clinic projects are real projects that meet a need of an external sponsor. In these projects, multidisciplinary teams of junior and senior engineering students work on projects under the direction of one or more faculty members. Projects can last a single or multiple semesters. The student teams typically communicate with the project sponsor to provide progress updates and ensure that the project focus remains appropriate. These projects typically culminate in final or progress reports and oral presentations to appropriate outside stakeholders.

One of the main objectives of the engineering clinic sequence is to help engineering students develop skills needed to be prepared for the real-world work environment. Many of these skills have been specifically codified as the ABET A-K criteria[3], listed in Table 1. The Junior and Senior Engineering Clinic project described herein is felt to be especially effective in that it addresses each of these criteria. However, quantitative assessment that shows how well students have actually developed these skills over the course of the clinic remains elusive. As with many engineering programs that have adopted PBL, Rowan University has yet to resolve how to best assess this aspect of the curriculum. However, employer and alumni feedback via assessment surveys gives us confidence that these skills have been developed via the curriculum and demonstrated in the workplace and/or graduate studies by graduates of the program[4].

Table 1. The ABET A-K criteria

A.	Apply mathematics, science, and engineering principles
B.	Ability to design and conduct experiments as well as interpret data
C.	Ability to design a system, component or process to meet the desired needs
D.	Ability to function with multi-disciplinary teams
E.	Ability to identify, formulate, and solve engineering problems
F.	Ability to understand professional and ethical responsibility
G.	Ability to communicate effectively
H.	Ability to understand the impact of engineering solutions in a global context
I.	Ability to recognize the need for and to engage in life-long learning
J.	Knowledge of contemporary issues
K.	Ability to use the techniques, skills, and modern engineering tools necessary for practice

The Clean Energy Program

In recent years, the state of New Jersey has strived to promote clean energy and energy efficiency throughout the state. For the engineering faculty, these goals presented an opportunity to develop a Junior/Senior Engineering Clinic project with many pedagogically desirable attributes.

The main objective of the CEP is to remove barriers that might otherwise prevent consumers from adopting clean energy technologies—specifically energy efficiency technology and wind power; or barriers that prevent consumers from making sound choices regarding energy conservation. Some efforts focus on basic awareness of technologies and available rebates and tax incentives, while other efforts focus on allowing consumers to make informed decisions by helping them calculate lifecycle costs and payback periods for potential investments. Targeted consumer populations included residential, small commercial, government and rural farm owners.

The program has operated under the principle that generating a collection of clean energy and energy efficiency success stories, while preparing engineers with an understanding of sustainability principles and a belief in the importance of sustainability, will lead to a gradual move toward clean energy production and energy efficiency within the state. Starting with those who are most predisposed toward these efforts, and helping them to make financially sound decisions will develop the widespread support that will allow more sweeping policy changes to occur. The CEP has been divided into four main project activities, summarized in Table 2. These activities include conducting clean energy symposia, compiling energy efficiency audits, maintaining the anemometer loan program support, as well as offering technical information support and outreach. Each project activity and applicable sub-activities are described in greater detail in the following sub-section. Additional activities have also included application of photovoltaic (PV) power and discussions regarding utility scale wind farms. Previous outreach and rebate efforts for PV by the NJCEP were extremely successful – there is currently a long queue of customers waiting to apply for a rebate program. As a result, outreach for PV power is currently deemphasized by the NJCEP. Research on the application of micro-hydro power in New Jersey is currently being planned.

Table 2. Summary of the four main project activities

1.	Clean Energy Symposia
2.	Energy Audits
3.	Anemometer Loan Program
4.	Technical Support and Outreach

Continued funding through state, municipal and private sources has allowed the project to run continuously for three years. Undergraduates working in the summer as paid interns, as well as graduate students supported through the program have helped to maintain the knowledge base that allows experienced students to teach new team members the various skills and sources of information needed to perform the required tasks. The program began in the fall of 2005. In the three years following, approximately 30 students participated in the program for credit in Junior or Senior Engineering Clinics, 10 students have participated in the program for pay over the summers, and 2 graduate students have been supported by the program.

Clean Energy Symposia

The Clean Energy Symposia aim to help consumers who are predisposed toward implementing clean energy and energy efficiency technology and measures move toward informed decisions. During the Clean Energy symposia, consumers see presentations on various technologies that are made by students, faculty and experts in specific technologies. At the same time, consumers come face to face with numerous clean energy technology manufacturers, suppliers, and installers, allowing them to ask the direct questions they need to move to the next step in implementation. This exposure to predisposed consumers has helped to stimulate strong participation from manufacturers, suppliers and installers. This participation has, in turn, helped to ensure the satisfaction of the attendees.

The key student deliverables for each symposium have included developing and making presentations on key topics, developing handouts on case studies, arranging for speakers, coordinating manufacturer, supplier and installer displays, and arranging for facilities and catering. Target audiences for these symposia have included small businesses, farm owners, educational administrators and residential consumers.

Energy Efficiency Audits

Most consumers lack adequate information regarding the sources of their current energy use needed to justify an investment decision of potentially many thousands of dollars in efficiency or in onsite clean energy generation. Many farm owners need reports from energy audits to be included as part of various Department of Agriculture grant applications. However, it can be difficult to identify energy professionals who will perform site-specific audits at an affordable fee for the small commercial customers or farm owners targeted by the CEP. Therefore, energy audits for commercial customers or farm owners have become an important aspect of the clinic project.

Investment grade facility audits have been performed for small commercial businesses, educational administrative buildings, rural farms and other key targeted customers within New Jersey. The final reports identify and quantify where and when electrical power is used; identify opportunities for conservation, either by modifying behavior or implementing technology; and estimate the site's potential for wind or photovoltaic generation of electricity.

Anemometer Loan Program

One impediment to increased small and terrestrial wind power in New Jersey is a lack of wind data that are sufficient for making a decision to invest in a wind turbine. The anemometer loan program is intended to assist farmers and communities make decisions about implementing small terrestrial wind power by providing wind data for a year that is specific to a location, through the loan of a mast and anemometer system and analysis of the subsequent wind data. Engineering students have procured, assembled, erected and taken down 20- and 30-meter-tall masts supporting anemometer systems at various sites in New Jersey.

Over the course of one year, wind speed and wind direction data are collected and analyzed by engineering students participating in the clinic project. At the end of the loan period, wind distribution graphs, wind rose concentration plots, and estimates of power that would be generated by various wind generation systems are presented. The final report includes cost benefit analyses that allow customers to make informed decisions about investing in one or more wind turbines. Currently, the program has 5 mast and anemometer systems, and has completed 7 site analyses. The program has been successful enough that there is currently a queue of over 20 parties interested in this program. This interest has been generated primarily by word of mouth. Preference for mast and anemometer loans are based on estimates of wind speed from National Renewable Energy Laboratory (NREL) resource maps, local zoning ordinances, and the likelihood of follow through with installing wind turbines at the end of the loan period.

Clean Energy Technical Support and Outreach

Many New Jersey residents have the financial ability and desire to implement an improvement in energy efficiency and/or renewable technologies but are held back by a lack of technical knowledge. The lack of information can result in inaction, or worse – inappropriate action. Outreach and technical support activities are intended to remove these critical information barriers and provide consumers with credible, reliable and understandable information that enables investment decisions.

The clean energy program website (www.rowan.edu/cleanenergy) is the key component for technical support, providing consumers with technical information, answers to frequently asked questions, links to other sources of information, and a specific email address and phone number for additional queries. In addition to managing the website and responding to email and telephone inquiries, students have developed case studies in various clean energy and energy efficiency topics. These case studies aim to remove informational barriers relating to clean energy technology adoption, provide the reader with an accurate understanding of how the particular technology operates and provide a detailed example of how the particular technology is implemented: its cost, lifetime, maintenance, paybacks, financing and economics. The completed case study is placed on the CEP website and distributed at symposia so that interested consumers can educate themselves with the financial impact of implementing various technologies.

Pedagogical Benefits of the Clean Energy Program

While providing valuable services to the community, students are also developing new technical skills, applying theory from courses, and addressing various A-K abilities. There is a constant focus on clean energy and conservation, which is coupled with the interaction with people who are interested in reducing their own carbon footprint (or their utility bills) but need help from the students. The result is that students are well aware of their potential to enact change on their community. It is hoped that this understanding fosters a belief that engineers have an ethical obligation to take a leadership role in public policy decisions, especially in regard to environmental concerns. These relate directly to ABET criteria F and H. Since the technical components of these tasks are not covered entirely by any of the four engineering programs offered at Rowan University, the project teams are multidisciplinary. Each team member must interact with, and depend on, other team members to handle some technical issues for the tasks.

Clean Energy Symposia

Organizing the Clean Energy Symposia requires the students to exhibit strong interpersonal skills. They must arrange for the facility, catering, speakers and vendor displays, while ensuring that there are sufficient attendees to make the event successful. In addition, students hone their formal public speaking skills by giving some of the presentations at the symposia.

Most of the presentations are not on material that has been directly covered in previous coursework. Instead, the students must make themselves experts on the various technical topics they are presenting on. In preparing for these presentations, students must leverage their formal education with additional research. Since the presentations must address practical and economic implications of various technologies, students must understand public policies such as zoning requirements, permitting, and tax and rebate incentives.

Energy Efficiency Audits

In addition to developing a marketable skill, performing energy audits is an excellent educational opportunity for the students. Students must interact with homeowners, business or farm owners to collect the information necessary to perform an audit. This information includes utility bills to determine the total energy used; as well as information about operating practices, such as when lights are turned on, HVAC set points, and the use of machinery.

One of the most challenging aspect of an energy audit is collecting an immense amount of information, and extracting the data that are important to performing the audit. All the pertinent data are never available, some are of questionable integrity, and often data are apparently contradictory. Needing to use ambiguous and incomplete data to reach conclusions is a challenge that is faced by most practicing engineers.

The students have numerous tools at their disposal to collect additional information for their analyses. They must determine how to best use Watts Up? and Kill-a-Watt meters to measure point uses of electrical energy, HOBO meters to measure temperature and humidity, and light meters to assess lighting levels. Combined with interviews and instantaneous measurements of electrical power, students can draw a reasonable overall picture of utility use in a building or facility.

Students analyze the utility use, suggest options for reducing energy use (including wind turbine and PV installation), estimate the economic impact of these suggestions, and compile a final written report for customers. This report is usually delivered in person, and includes a face-to-face meeting to discuss and explain the contents of the report.

Anemometer Loan Program

Students participating in the Anemometer Loan Program must exhibit many of the abilities defined in the ABET A-K criteria. During the data collection year, students analyze and record wind speed, wind direction and average power ratings from the various anemometers that are in service. From the collected data, students are able to determine wind distribution and plot wind rose concentration. Ultimately, a complete year of data allows students to estimate the power generated and payback periods for different types of wind turbines. This information is passed on to the customer in the form of a final, written report. Monthly summaries of the data are posted on the website and made available to the public.

In addition to the data, there are many activities that support generating the data. For example, each time anemometer is removed from service, its calibration is verified in a wind tunnel. At the beginning of the data collection cycle, the tower must be erected, and at the end of the cycle, the tower must be removed. Students have become very capable in using a gin pole, winch and pulley system to raise and lower towers. Students are also designing a system based on a weather balloon that can be used to perform short term studies to identify ideal locations within a specific site. This system is currently undergoing verification studies.

An important part of this task is to understand the various zoning requirements set forward by each of more than 500 municipalities in New Jersey. Students identified all of the municipalities that National Renewable Energy Laboratory (NREL) resource maps suggest have average wind speeds that might be sufficient to justify a wind turbine. They are currently in the process of contacting all of the zoning officials to determine zoning requirements to place a 30-meter tall, temporary mast on private property in each municipality. The results are tabulated, and a color-coded map of the state is being developed.

Clean Energy Technical Support and Outreach

For the Technical Support and Outreach tasks, students have developed and are managing a website that serves as a portal of information for homeowners, small business owners, and farmers. The site includes answers to frequently asked questions, case studies for specific technologies, information on the anemometer loan program, and an email address and telephone number to direct further inquires. Students respond to the specific questions they receive over email and telephone. Sometimes the questions are straightforward, but sometimes they require additional research on the part of the student.

Students have also developed case studies to post on the website and distribute at the Clean Energy Symposium. Much like the presentations at the symposium, these case studies require students to perform additional research, which emphasizes the need for lifelong learning.

Summary and Conclusions

The clean energy program has proven to be an excellent vehicle for multidisciplinary project-based learning for engineering students. Likewise, it has provided valuable services for many small businesses and farms in the state. As an ongoing operation, new students on the project learn skills from more experienced students. Graduate students and summer internships have helped to maintain continuity of the knowledge base.

The various tasks in the program require students to apply basic math, science and engineering principles, as well as to learn techniques, skills and tools that are essential to engineering for sustainability. These were explicitly listed in the previous section, and summarized in Table 4. The various tasks also address each of the ABET A-K criteria. These were specifically discussed in the previous section, and are summarized in Table 5.

Table 4. Principles and techniques needed for the main project tasks

Task	Math, Science and Engineering Principles.	Techniques, Skills and Tools
Clean Energy Symposia	Specific to presentations	Specific to presentations
Energy Audits	Electrical theory Heat transfer	HOBO meter Watts-Up? meter Kill-a-Watt meter Light meter Excel
Anemometer Loan Program	Statistics	Tower erection Wind speed datalogger Excel GIS Wind tunnel
Technical Support and Outreach	Specific to questions Specific to case studies	Specific to questions Specific to case studies Web site development

The program has operated under the principle that generating a collection of clean energy and energy efficiency success stories, while preparing engineers with an understanding of sustainability principles and a belief in the importance of sustainability, will lead to a gradual move toward clean energy and energy reduction within the state. Starting with those who are most predisposed toward these efforts, and helping them to make financially sound decisions will develop the widespread support that will allow more sweeping policy changes to occur.

Table 5. ABET criteria addressed by task

ABET Criterion		Clean Energy Smposia	Energy Audits	Anemometer Loan Program	Technical Support and Outreach
A.	Apply mathematics, science, and engineering principles	X	X	X	X
B.	Ability to design and conduct experiments as well as interpret data		X	X	
C.	Ability to design a system, component or process to meet the desired needs			X	
D.	Ability to function with multi-disciplinary teams	X	X	X	X
E.	Ability to identify, formulate, and solve engineering problems		X	X	X
F.	Ability to understand professional and ethical responsibility	X	X	X	X
G.	Ability to communicate effectively	X	X	X	X
H.	Ability to understand the impact of engineering solutions in a global context	X	X	X	X
I.	Ability to recognize the need for and to engage in life-long learning	X			X
J.	Knowledge of contemporary issues	X		X	X
K.	Ability to use the techniques, skills, and modern engineering tools necessary for practice	X	X	X	X

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