AC 2010-677: A GREEN TECHNOLOGY COURSE IN A COMMUNITY COLLEGE

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A Green Technology Course in a Community College

Abstract

This paper describes a Green Technology course taught for the first time in 2009 and two brief summer bridge programs offered at a community college in 2008 and 2009.

The summer bridge programs were organized around the theme of the generation of electricity from renewable sources and provided an introduction to engineering and technology for new students. Green Technology is a semester-long course which equips students to explore lifestyle changes that will enable them to reduce both their personal and community carbon footprint, resulting in a greener society.

Content outlines for the two summer bridge programs are presented along with an independent evaluation of student outcomes for the 2009 summer bridge program. Pre- and post- surveys were administered to participants in 2009; the data were then analyzed statistically and reported upon by an outside evaluator.

The development of the Green Technology course is described and details of the course as taught are presented. The topical outline and the student assignments for the Green Technology course are also included.

Introduction

A bridge program for new community college students was first held in the summer of 2008. This four day program explored some of the science, technology, engineering, and mathematics behind the generation of electricity by wind, water, and solar power. Student enthusiasm proved sufficiently promising that a semester-long Green Technology course was developed in the fall of 2008 and offered for the first time in the spring of 2009. A second summer bridge program was offered in the summer of 2009.

The Green Technology course enables students to explore lifestyle changes that will empower them to reduce both their personal carbon footprint and that of the community, resulting in a greener society. The development of this course is a prime example of taking an idea and properly supporting its growth with grants, faculty and administrative support, and encouragement from society.

The genesis of this course was a 2003 partnership between an NSF grantee, several technical schools, and several community colleges. The objective of the grant was to create leaders in the community colleges and high schools who would be able to develop technology/engineering education projects in energy and power technologies. During 2004 and 2005, workshops were developed and implemented to increase engineering awareness for the participating high school teachers. Several alternative energy lesson modules on wind and solar power were designed, tested and modified.

The development of the course accelerated when the community college partnered with a major university on another NSF grant. This partnership supported the community college as it developed and implemented two programs for new engineering technology and engineering science students: The Summer Bridge to Alternative Energy Engineering in 2008 and The Summer Bridge to Green Technology in 2009.

The Green Technology instructor acquired additional experience in the summer of 2009 through a grant-funded research opportunity in engineering at another major university. During that summer, a new lesson module was developed which was implemented in the Green Technology course during the spring of 2010.

Summer Bridge 2008 Description

The Summer Bridge to Alternative Energy Engineering program in 2008 allowed students to explore the technology and engineering of alternative energy systems with hands-on activities that concentrated on wind and solar power design projects. Enrollment was limited to 20 participants and preference was given to both new and returning community college engineering and technology students with fewer than 15 earned credits. Each participant received a $25 per day stipend ($100 total for attending all four days). Descriptions of the activities of each summer bridge program are included in the Appendix.

Green Technology Course Description

The Green Technology course is a three-credit course consisting of two lecture and two lab hours per week. Students explore lifestyle changes that empower them to reduce both their personal and community carbon footprint, resulting in a greener society through technology. The course also introduces the theoretical and practical concepts of energy sources with an emphasis on solving problems related to sustainable renewable energy use and conservation. Topics include carbon footprint calculations, the expanded use of wind, solar and hydroelectric power. With hands-on lab experiments, elementary engineering projects and computer internet research, students discover several aspects contributing to carbon emissions and developing a low carbon diet.

Green Technology Course Work and Activities

Green Technology begins with introductions and some critical thinking puzzles. The puzzles require group interaction which serves to "break the ice" for students. After the group activity is completed, an overview of the course is presented. The first key topic of the course is the basic fundamentals and theory of direct current (DC) electricity and electric circuits.

Having an understanding of basic electricity is necessary before discussing alternate energy. The students, working in pairs, are given a light bulb, battery, and wires and instructed to *"light up the bulb."* The task itself is not difficult and the students typically do well. However, the purpose of the activity is to generate dialogue regarding electricity and some key components in electric circuits. Terms such as open and closed circuits, energy source and load, electric schematic, voltage, current and resistance are all discussed.

Following the simple battery and light bulb activity, a lesson is completed which utilizes both Ohm's Law (V=I*R) and the relationship between voltage, current and power in an electric circuit which is sometimes called Watt's Law (P=V*I). This lesson is supported by a demonstration using a light bulb and a power supply. The instructor increases the voltage on the supply while the students observe the brightness of the light bulb. The students observe how an increase in voltage causes an increase in the amount of light being emitted by the bulb. This demonstration opens a discussion regarding Ohm's Law and Watt's Law. The students discover first hand the importance of a mathematical understanding of a science concept. Also, the demonstration concept sets the foundation for the understanding of energy consumption and carbon footprints. Following the Ohm's Law and Watt's Law activity, the participants build both series and parallel DC electric circuits. The hands-on lesson uses SNAPS circuits. The students are exposed to the voltage and current relationships when loads are put in series and when they are put in parallel. Again, the mathematics and equations for parallel and series circuits are emphasized. The students are asked to put the experiment data into tables and provide graphs of voltage vs. current.

Once all the electric circuit activities are finished, time is dedicated to focus on reflection of material learned and discuss the engineering connection to the activity. Every day we are surrounded by circuits that use parallel and series circuitry. Complicated circuits designed by electrical/electronic engineers are composed of many simpler parallel and series circuits. During the activities, students build simple circuits and explore the properties of electric circuits. After completing the section on DC electricity and its related circuits, the course moves toward the generation of alternating current and AC circuits. The participants are exposed to the fundamentals of magnetism, electromagnetism and Faraday's Law ($V_{ind} = N\, d\varphi/dt$) through a PowerPoint presentation, worksheets and lab demonstrations.

Now that the participants have a grasp of these fundamentals, the operation and theory of a simple AC generator is introduced. The effects on the generator's output voltage due to the number of pole pairs, the number of turns in a conductive loop and the angular velocity of the turbine is also discussed in detail. Subsequent to the generation of AC electricity, the students are exposed to the essential concepts and terms of a sinusoidal waveform. The electricity that is supplied to modern day homes is alternating current (AC). A mathematical model for AC is a sinusoidal waveform of approximately 170 Volts peak value with a frequency of 60 Hz.

It is very important for the students to understand these basic concepts and to learn how they are related and interchanged. Terms such as peak voltage, rms voltage ($V_{rms} = 0.707*V_p$), period (T) and frequency (f =1/T) are covered. At this point in the AC activity, the relationship between voltage, current, resistance, and power are re-introduced with a discussion about how the relationships relate to AC circuits. The DC battery source can be replaced with an AC source in the previous series circuits. As a result, parallel resistive circuits and all the calculations would be the same except that the source is a sine wave. Additionally, sinusoidal terminology would have to be used in the calculation and reporting of data. This is a key connection to the previous DC activities.

The concept of energy and power is introduced after the students have a core understanding and terminology of AC electricity. Calculations of power, energy and their relationship to household electric appliances and electronic devices are covered. The kilowatt-hour (kw-hr) is discussed in detail because the power rating of an appliance is an indicator of how much electricity is used while operating the appliance. When the amount of time an appliance is used has been determined, the energy (kw-hr) for each appliance can be calculated. Energy is the amount of power used in a given time.

An excellent design project is the follow-up to the energy and power activity. The students, working in pairs, are instructed to calculate "*A Modern Kitchen's Carbon Footprint.*" Students design their modern kitchen by choosing and listing the electric appliances they would like to have. Their assignment is to determine the kitchen's lighting scheme and wattage of various kitchen household appliances. (A list of appliances and wattage ratings is provided or can be researched on the internet.) Once they know their appliances and wattage ratings, the students can calculate the number of kilowatt-hours used by the entire kitchen.

Next, students calculate the cost of electricity to run the kitchen. Typically, students will use their home electric bills to identify the cost per kilowatt-hour. After the cost is calculated, students will calculate the amount of CO_2 emitted into the atmosphere due to the energy consumption of the kitchen. Students can research, by their zip code, the amount of carbon released per kilowatt-hour of energy consumed. Finally, students are asked to discover the use of alternate energy resources to offset the CO_2 emitted. For example, calculations for the cost and size of a photovoltaic system to support their kitchen can be performed. The kitchen activity package could also be expanded to include calculating the electric energy consumption of an entire household using a comprehensive list of the wattage rating of other household appliances. Additionally, the need to limit the use of appliances to conserve energy is also discussed. The students dedicate some time to reflect upon and discuss feelings (negative and positive) that people may have about conserving electrical energy. Conservation often takes willpower, the development of new habits and lifestyle changes.

Following the fundamentals of both AC and DC electricity, the course moves to the storage and distribution of electricity. This concept is important with respect to alternative energy. Both photovoltaic (solar power) and wind turbines can generate electricity, with the generated electricity used directly or stored by charging batteries. Several systems can be implemented, depending on the application. Therefore, a basic understanding of how electricity is distributed from the power plant to local homes is essential.

The distribution lesson begins with assigned readings; "Pearl Street Station: The Dawn of Commercial Electric Power" and "War of Currents." The opening of the Pearl Street station in lower Manhattan in September, 1882, allowed Thomas Edison to publicly present a complete system of commercial electric lighting, power and distribution. In the late 1880s, George Westinghouse and Thomas Edison became adversaries due to Edison's promotion of direct current (DC) for electric power distribution over the alternating current (AC) advocated by Westinghouse and Nicola Tesla. These articles stimulate a discussion on the two forms of electricity. This section is concluded with the viewing of the PBS video; "Tesla – Master of Lightning."

In order to understand today's method of distributing electricity, the fundamentals of transformers are covered. The participants are exposed to concepts such as turns ratio as well as step-up and step-down transformers which demonstrate how voltage can be increased and decreased for efficient distribution to homes. Also, converting AC to DC by rectifier circuits is covered as well as battery chargers and power supplies. The battery charger is an important topic to learn because everyone has a number of rectifiers at home.

Once the foundation of energy cost, consumption, storage, distribution and the carbon footprint relationship is established, the course shifts to the concept of using nature as an energy source. The first alternate energy lesson the students are exposed to is wind power. Harnessing the wind to generate useful energy is discussed. Simple AC generator theory and Faraday's Law are reintroduced in this section of the course. The students construct a basic vertical axis wind generator based upon the Savonius design. The Savonius wind turbine, designed in 1922, mounts two half cylinders on a vertical shaft. It is simple to build and can accept wind from any direction. However, the Savonius turbine is less efficient than the more common horizontal axis wind turbines because of aerodynamics: the horizontal turbine blades are designed to create lift to spin the turbine rotor. The Savonius turbine, on the other hand, operates on the concept of drag where one side of the vertical cylinder creates more drag in moving air than the other. This causes the shaft to spin.

The construction of the model turbine also reinforces the concept of Faraday's Law ($V_{ind} = N\, d\varphi/dt$). A changing magnetic field induces a voltage in a coil that is directly proportional to the rate of change in the magnetic field ($d\varphi/dt$) and the number of turns in the coil (N). The wind turbine model makes its electricity with a simple generator producing pulses of current. It does so by passing strong earth magnets over coils of fine wire (28 AWG magnet wire). Each time a magnet passes over a coil, an induced voltage is created. The coil becomes energized with electricity. When four coils are connected together in series, the induced voltage is quadrupled. Enough voltage and current are generated to light up a series of LED bulbs. This is a simple and efficient way to generate electricity. Also, this is the same basic principle used in almost all turbines, even large-scale commercial ones.

The electricity from a wind turbine varies both in amplitude (V_{ind}) and frequency (f) with wind speed. The students are exposed to this concept by observing the electrical output of their small model wind turbine via an oscilloscope. As the wind generated by a floor fan is increased, the students observe on the oscilloscope that both the induced voltage and frequency of the electricity produced by their modeled turbine increase. This concept was shown to be supported mathematically by Faraday's Law and [f = (# of pole pairs) *(revolutions per second of the shaft)].

Following the hands-on activity, a discussion around how to make practical use of the electricity created by wind turbines is held. Electricity from wind turbines can be converted, through additional electronics, to a stable DC voltage which can then be used to charge batteries. The electrical output of wind turbines can also be tied directly to the electric grid. However, this requires some additional electronics to make sure the turbine output voltage is synchronous to the AC electricity generated at the power plant.

The next concept covered in this course which uses nature as an energy source is hydroelectric power: using water power to produce electricity. The first task is to provide a qualitative theory of water power usage as well as a discussion about the impact of water power historically and locally. This discussion is very productive because of the community college's location within an area central to America's Industrial Revolution. The curriculum also includes simple fluid mechanics and terms such as head, flow and diameter of a pipe. The quantitative section of the water power activity is to discover the principles of the flow equation, *[Q = 0.62 * (cross-sectional area)*(2gh) 1/2]*. This equation is supported with handouts and worksheets that incorporate problems for the students to solve. As water falls, it is a potential source of energy. The greater the height (head) from which the water drops, the greater the potential energy.

After both the water and wind power lessons are completed, the course continues following the alternate energy theme by devoting time to solar energy. Photovoltaic cells are introduced to the class with a clarifying discussion on how the cells convert solar energy into useable electricity. Terms such as solar PV cells, modules, panels and arrays are also discussed. The participants conduct a hands-on activity with photovoltaic cells. Outside, they measure and calculate voltage, current and power of circuits with cells in parallel and/or series combinations. Using the data they gather in their outside solar experiments, the students design a photovoltaic system, using the lab PV cells that will produce enough DC electricity to run a DC refrigerator. The refrigerator's power and voltage specifications are provided or can be researched on the internet. The design has to take into consideration the combination of parallel and series source circuits. In addition, the numbers of PV cells and total surface area have to be calculated.

After this exercise, the class is introduced to solar heating systems along with a brief discussion about system operation. To gain an appreciation of the amount of energy provided by the sun, the class designs solar cookers. Working in pairs, the students design, build and test their solar cookers. Each group receives the same amount of room temperature water and identical vessels to hold the water. Outside in the sun, the water containers are put into the solar cookers. The students have to observe both the time and the temperature of the water. The experimental data is then graphed, and each group presents their design and data. The information is then compared to the purchased solar cooker that was assembled by the instructor. The participants have a great time outdoors with this activity. Some of the teams also get a little competitive regarding how hot the water gets inside their solar cookers.

Finally, the course ends with the students developing a plan for a low carbon emission diet. This section of the curriculum lasts approximately three weeks. Students work in groups of three or four. They simulate they are living in one house under one roof, or they can simulate living in their own house with the group members are neighbors. Nothing beats going on a diet with someone else to provide support. Students calculate the carbon footprint for their simulated homes by taking inventory, room by room, of all items that consume electricity. Students draw from their real life situations to help with this exercise. They look at their driving patterns, the heating of their homes and examine their basic life style. Once students have an understanding of their yearly carbon footprint, they develop a strategy to reduce their carbon emission. This can be achieved through efficiency, introduction of alternate energy sources, procuring carbon credits, etc. The course ends with students presenting their low carbon emission diet plan.

New Lesson Module

During that summer of 2009, the course instructor was immersed in an inquiry-based learning experience through a grant-funded summer research opportunity in engineering at a major university. A new lesson module, *"Which Bulb is Best,"* was developed from this experience. The new module is being implemented in the Green Technology course during the spring of 2010.

This inquiry-based lesson module exposes students to energy consumption of different kinds of light bulbs used in everyday households. Students will develop an experiment to measure the amount of light generated using different technologies and power rating as indicated on the light bulb package, (with respect to the amount of light being emitted from the bulb), of common household light bulbs. Students will be provided materials and must develop an inquiry that will include a hypothesis, experimental procedures, data analysis and conclusion. For example, students will measure LED, CFL and incandescent light bulbs and will be able to calculate the overall cost of the light bulbs. The calculation includes initial, replacement and energy consumption cost. Additionally, students will be able to calculate the carbon footprint of each light bulb and evaluate cost, environmental impact, quality and quantity of light for each given light bulb technology.

This lesson module is designed to enlighten students and help them become more educated energy consumers in our society. The material for each lab set-up ranges between $65 and $170. The materials used in the lesson are a "Kill-A-Watt" meter, a light sensing meter, a light bulb socket with reflector, and LED, CFL and incandescent light bulbs. Photo resistors and a multimeter can be substituted for the light sensing meter, if necessary. The students submit a report consisting of a one-page description of their experiment, carbon foot print calculations, cost analysis and their recommendations, and deliver their findings in a classroom presentation.

Outside Evaluator's Report on 2009 Summer Bridge Program

In a report dated October 19, 2009, the evaluator wrote:

> **Summary**
>
> The following provides a brief summary of a survey conducted among [community college] students enrolled in [community college]'s Summer Bridge to Green Technology program, held on August 24-28, 2009, as funded by the [redacted] grant, …. The survey, …developed at [redacted] and subjected to extensive validation tests, explores student attitudes toward academics, school, the occupation of engineering and the respondents' aspirations to enter the engineering occupation. The 20-item survey uses a 4-point Likert scale and was administered to fifteen students at the beginning and conclusion of four days of [community college] project activities. Table 1 below summarizes the findings by domain and then again for the overall instrument. Note that the students reported significant gains in three of the four domains, as well as on their overall scores. The effect size for the overall gain was 0.52 (eta-squared), a very solid finding.

Table 1: Pre-Post by Domain

Domain	Pre	Post
Academics (Q1-5)	16.23	18.08*
College (Q6-9)	13.00	14.77*
Engineering Occupation (Q10-16)	24.08	26.00*
Engineering Aspirations (Q17-20)	12.54	13.92
Total	66.25	73.25*

*Significant at $p<.05$ (paired samples t-test)

Looking at the data on an item-by-item basis, [the evaluator] found that the students reported significant gains on 45% of the items.

Table 2: Pre-Post by Item

Item	Pre	Post
1. I do my college work as well as my classmates.	3.13	3.77*
2. I am good at solving problems in mathematics.	2.80	3.31*
3. I am good at solving problems in science.	3.13	3.54
4. I use computers as well as my classmates.	3.27	3.77
5. I am good at working with others in small groups.	3.53	3.69
6. I like being a student at my college.	3.47	3.69
7. Being a student at my college is important to me.	3.20	3.77*
8. I make friends easily at my college.	2.93	3.46*
9. The professors at my college want me to do well in my college work.	3.40	3.85*
10. Engineers solve problems that help people.	3.40	3.69*
11. Engineers work in teams.	3.40	3.69*
12. Engineers design everything around us.	3.20	3.46*
13. There is more than one type of engineer.	3.53	3.77
14. Engineers use mathematics.	3.47	3.69
15. Engineers Use science	3.33	3.69
16. Engineers are creative.	2.87	3.67
17. When I graduate I want to be an engineer.	3.36	3.38*
18. When I graduate I want to solve problems that help people.	3.18	3.77
19. When I graduate I want to design different things.	3.13	3.54
20. When I graduate I want to work on a team with engineers.	3.13	3.23

*Significant at $p<.05$ (Wilcoxon)
Scale: 1=I strongly disagree; 2=I disagree; 3=I agree; 4=I strongly agree

Overall, [the evaluator] concludes that these findings clearly point to the high degree of effectiveness of the project with the participating students. Some of the gains (for example, the spike in mathematical self-efficacy seen in Question 2) are quite striking. While the change in the aspirations to become an engineer did not vary much after the four-day experience, the students nevertheless seemed have received real benefits from their participation, both in terms of their own studies and their appreciation for the work of engineers more generally.[2]

Conclusions

Because the lesson modules developed for the Green Technology course are versatile, they can be used together to form a full semester course at the community college. In addition, the modules can be simplified for use within an engineering/technology summer bridge program focused on helping incoming freshmen get comfortable with college and faculty.

The Green Technology modules are also attractive to students because they include current technology and social issues as they incorporate a variety of enjoyable, hands-on activities. While the modules are algebra-and trigonometry-based, there may be students who struggle with calculations. However, the instructor can easily step in and provide guidance to handle this situation as the modules are not heavily weighted with mathematics. An added benefit is that students might enhance their view of their ability to solve of both math and science problems because of the Green Technology subject matter.

In addition, students participating in the course gain an appreciation for the work engineers do and the problems they are trying to solve, which may spark additional interest in this course of study. Finally, these lesson modules can be used in professional development workshops for K-12 educators and advance teachers in STEM education.

For the future, the Green Technology course and lesson modules are being modified and improved. As technology in this field matures, new modules will be developed. For example, the college is developing a new fuel cell lesson module to complement the current curriculum. When finalized after appropriate feedback, this module will be added to the 2010 summer bridge program.

Appendix

Summer 2008 Bridge to Alternative Energy Engineering

Day 1: Pretest
Technology and Engineering
Engineering & Scientific notation
Light Bulb Experiment
DC Circuits, SNAP Circuits and Digital Logic
Multisym
Review Wind Turbine Projects- Check parts list
Day 2: Photovoltaic Cells
Fundamentals of AC electricity
Sine wave, Period, Frequency and Amplitude
How AC electricity is made
Wind Turbine Construction
Day 3: Wind Turbine Construction (cont.)
Testing Wind Turbine
Day 4: Carbon Footprint of a Modern Kitchen
Post Test

Summer 2009 Bridge to Green Technology Engineering

Day 1: Pretest
Technology and Engineering
Engineering & Scientific notation
Introduction to DC Circuits,
SNAP Circuits and Multisym
Greenhouse effect and history of burning fossil fuels
Day 2: Energy and power Relationship (Potential vs. Kinetic Energy)
Renewable Energy
Wind power
Solar energy
Save by the Sun - DVD Video
Mixed Bag - Article Assignment
Savonius wind Turbine Project
Day 3: Testing a Wind Turbine
Fundamentals of AC Electricity and Generation
Sine Wave, Period, Frequency, and Amplitude
Photovoltaic Cells
Energy Calculation, Efficiency, and Conservation
Day 4: Carbon Footprint Calculations
Post Test

Green Technology Course Topics and Assignments

WEEK	TOPICS	ASSIGNMENTS
1	Introduction/Technology Timeline	Read pages 4-14 of "Technology & Society" and Read pages 25 – 36
2	DC & AC Electricity Fundamentals SNAP Circuit Projects and Light Bulb Experiment Rectifier and Inverter Circuits – Tesla Video & Articles	*Handouts*
3	Carbon Footprint Calculations and CO_2 emissions "Carbon Footprint" of a Modern Day Kitchen" Project	*Handouts*
4 & 5	"Which Bulb is Best?" Project **Exam #1**	
6 &7	Energy & Power Relationship Renewable Energy ▪ Wind & Solar Power ▪ Hydroelectric Power ▪ "Power by the Sun" - DVD Video	*Read pages (102 – 214)* *"Mixed Bag" Article assignment*
8 & 9	Savonius Wind Turbine Project Solar Cooker Project Photovoltaic Calculation Project	*Handouts*
10	"Heat" - DVD Video Energy Calculation, Efficiency and Conservation Energy Consumption Project	*Handouts*
11	"Green" Environmental Practices, Recourses, Economy, Jobs **Exam #2**	
12	Case Study: Green Analysis *(topics to be provided by instructor)*	
13 – 15	**Introduction to Low Carbon Diet Project**	Read pages 1-5, "Low Carbon Diet"
	"Low Carbon Diet" -- Team Initiator, Team Building and Information Meetings	Read pages 58-62
	"Low Carbon Diet" -- Lifestyle Practices	Read pages 63-65 & 7-22
	"Low Carbon Diet" -- Household Practices	Read pages 66-68 & 25-38
	"Low Carbon Diet" -- Empowering Others	Read pages 69, 70 &41-49
	"Low Carbon Diet"-- Student Presentations	

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