AC 2008-1235: PROFESSIONAL DEVELOPMENT INSTITUTES ON ALTERNATIVE ENERGY

Michael Pelletier, Northern Essex Community College

Lori Heymans, Northern Essex Community College

Paul Chanley, Northern Essex Community College

Professional Development Institutes on Alternative Energy

Abstract

This paper describes three Professional Development Institutes for middle and high school teachers exploring the science, technology, engineering, and math behind the generation of electricity by wind, water, and solar power.

Each institute was organized and delivered as a Web-companion course. All lecture notes, assignments, and required readings were provided on-line and participants were able to submit assignments on-line. Three graduate credits from Endicott College were made available to participants in each institute. After the summer sessions of each institute, participants designed and field tested in their own classrooms a lesson on alternative energy. At the end of each institute, participants received kits of small electrical parts or SNAP circuits and digital multi-meters to use with their classes.

During the summer of 2006, a 45-hour Summer Content Institute entitled **STEMS** (Science, Technology and Engineering for Middle Schools) was held at Northern Essex Community College in Massachusetts. The **STEMS** Content Institute provided educators at the Grade 6-12 level with science and engineering/technology content and context. The content was aligned with the Massachusetts Curriculum Frameworks for Science and Technology/Engineering and with the Massachusetts Curriculum Frameworks for Mathematics and provided solid integration of key scientific and mathematical concepts with the engineering design process. In this institute, participants explored the generation of electricity by the alternative energy sources of wind, water, and solar. Participants engaged in lab activities, completed worksheets and visited a “Green Home” powered by a wind turbine and by both passive and active solar energy. During the fall of 2006, the participants met with the community college faculty to share their personally designed lessons and results.

During the summer of 2007 Northern Essex Community College hosted a similar 45-hour Professional Development Institute entitled **Alternative Energy**. In November of 2007, the participating teachers returned to the community college to meet with the faculty and share their personally designed lessons and the results.

Also during the summer of 2007, a 30-hour Professional Development Institute, entitled **Alternative Energy for STEM Fellows,** was held at the community college.

An outside evaluator used pre and post tests of participating teachers to evaluate the **STEMS** Content Institute of 2006. The Office of Institutional Research at Northern Essex Community College analyzed the pre and post tests completed by participants in Northern Essex Community College both Content Institutes held in 2007. The results of all three evaluations are included in this paper.

Introduction

This paper describes three Professional Development Institutes for middle and high school teachers exploring the science, technology, engineering, and math behind the generation of electricity by wind, water, and solar power.

Each institute was organized and delivered as a Web-companion course. All lecture notes, assignments, and required readings were provided on-line and participants were able to submit assignments on-line. Three graduate credits were made available to participants in each institute through a local college's graduate school. After each institute, participants designed and field tested in their own classrooms a lesson on alternative energy. At the end of each institute, each teacher received a kit of small electrical parts or SNAP circuits and a digital multi-meter to use with his or her classes.

During the summer of 2006 a 45-hour Summer Content Institute entitled **STEMS** (Science, Technology and Engineering for Middle Schools) was held at Northern Essex Community College in Massachusetts. The **STEMS** Content Institute designed by the community college's engineering faculty and funded by the Massachusetts Department of Education, provided educators at the Grade 6-9 level with science and engineering/technology content and context. This material was aligned with the Massachusetts Curriculum Frameworks for Science and Technology/Engineering and with the Massachusetts Curriculum Frameworks for Mathematics and provided solid integration of key scientific and mathematical concepts with the engineering design process. In this institute, generation of electricity by the alternative energy sources of wind, water, and solar power was explored. Participants engaged in lab activities, completed worksheets and toured both a small-scale hydroelectric plant and a "Green Home" powered by a wind turbine and by both passive and active solar energy. In keeping with the standards of the Massachusetts Curriculum Frameworks for Science and Technology/Engineering for grades 6-8, material on construction and bridges was included. At the conclusion of this institute, a participant could elect to receive either 65 PDPs at no charge to the participant or 3 graduate credits from Endicott College at the participant's expense. Participants choosing to receive graduate credit were enrolled in a graduate course at the local college's graduate school and were graded on their work during the summer by the community college instructors of the institute. Grades were submitted in September. During the fall of 2006, after grades had been submitted, the participants met with the community college faculty to share their personally designed lessons and the results of using the lessons in their classrooms.

During the summer of 2007, Northern Essex Community College hosted a similar 45-hour Professional Development Institute entitled **Alternative Energy**, slightly modified in content and again funded by the Massachusetts Department of Education. Instead of a visit to a Green Home, participants visited a Green Corporate Building which is LEED Certified Platinum. At the conclusion of this institute, a participant could elect to receive either 65 PDPs at no charge to the participant or 3 graduate credits from Endicott College at the participant's expense. Participants choosing to receive graduate credit were enrolled in a graduate course at the local college's graduate school. In 2007 in contrast to 2006, grades were based on both assignments done during the summer and on the classroom lessons designed and tested in the teachers' classrooms during the fall. In November of 2007, the teachers returned to the community college to meet with the faculty and share their experiences using the lessons in the classroom.

Also during the summer of 2007, a pared-down, 30-hour Professional Development Institute on **Alternative Energy for STEM Fellows** was held at Northern Essex Community College. This course was designed for middle school teachers who were STEM Fellows of the Northeast Regional Pre-K-16 Network. The Northeast Regional Pre-K-16 Network is funded by a grant awarded by the Massachusetts Board of Higher Education (BHE) from the STEM Pipeline Fund. The STEM Pipeline Fund is a workforce development initiative of the State of Massachusetts designed to increase student interest and teacher preparation in STEM subjects. Those STEM Fellows who wished to receive 3 graduate credits (45 hours) were required to attend 2 additional days in the summer and were required to design and field-test a written lesson plan and then share the experience using the lesson with the other STEM Fellows.

Objectives of Content Institutes

Teacher-participants would be able to

- explain the science, technology, engineering and/or mathematical topics listed in the Topical Syllabus included in the Appendix;
- demonstrate the application of the topics to Alternative energy systems;
- specify which standard(s) of the Massachusetts Curriculum Frameworks for Science and Technology/Engineering and/or Mathematics is/are addressed by each of the topics.
- Design, field-test and modify a written lesson plan that references the supporting science and/or engineering topics, the associated mathematics, and the application of the topic(s) to alternative energy systems. The assignment required that the developed lesson include hands-on activities as well as pre- and post- assessments of student knowledge.

Description of Group Participants

All participants in the three content institutes came from public schools in Massachusetts. Twelve taught in high schools and twenty-one taught in middle schools. Two of the thirty-three participants taught at charter schools.

The educational background in science, engineering, or mathematics of most teacher participants was limited. In the 2006 Alternative Energy Institute, one high school teacher had an undergraduate degree in Engineering; two had degrees in Biology; and one had a degree in Chemistry. In the 2007 Alternative Energy Institute, two participants had engineering degrees; one had a degree in Math; and one had a degree in Physics. In the 2007 Institute for STEM Fellows, one teacher had a degree in Plant Science and one in Natural Science/Geosciences.

More details on the participants may be found in the tables in the appendix.

Instructional Team

- The principal investigator was a former full-time faculty member at the community college with a BEE and an MSEE degree who had taught computer and electronic engineering as well as mathematics through Calculus II.
- In 2006, all of the instructors for the content institute were chosen from the full-time faculty ranks. Two of the four community college faculty members were electrical engineers experienced in teaching electronic technology and/or electrical engineering courses as well as college-level mathematics courses. One had earned a B.S. and an M.S. in Electrical Engineering; the other, a woman, had earned a B.S. in Electrical Engineering and an M.S. in Applied Mathematics.
- A third faculty member was a Mechanical/Aeronautical Engineer with an M.S. in Aeronautics who had previously taught in the Engineering Science program and was now teaching in the Mathematics Department. He was part of the instructional team for both summer Content Institutes, but not for the 30-hour Alternate Energy for STEM Fellows course.
- The fourth faculty member was the designer and owner of the "Green home" used for a site visit. He had a Ph.D. in Chemistry and taught Engineering Physics at the community college.
- In 2007, this fourth faculty member retired and was replaced by a woman electrical engineer who had worked in the solar energy field and was now teaching at a local high school.

Course Description

The 45-hour *Science, Technology and Engineering for Middle Schools* Summer Content Institute of 2006 and the 45-hour *Alternative Energy* Professional Development Institute 2007 were similar courses in substance and presentation. The 30-hour *Alternative Energy for STEM Fellows* course differed principally in not having any material on construction technology, nor in having a visit to a Green Building made mandatory. The summer institutes provided educators at the middle school and high school levels with key scientific and mathematical concepts of alternative energy generation accompanied by the engineering design process.

The institutes were organized and delivered as Web-companion courses. All lecture notes, assignments, and required readings were provided on-line and participants were able to submit assignments on-line.

The first two institutes met 9 AM to 12 and 12:30-2 PM, five days per week for two weeks. The 30-hour *Alternative Energy for STEM Fellows* course met for 6 hours per day for one week. After the completion of summer activities, follow-up sessions were held in the fall. The follow-up was crucial to the success of the institutes, since it was at these sessions that participants of the summer institutes presented their lesson plans to both the community college faculty and their fellow colleagues from the middle/high schools. The lesson plans had been designed and developed and then field-tested by each teacher in his or her classroom. The fall follow-up provided a positive environment for dialogue on what worked and what did not work in classrooms, as well as ideas for continuing improvement.

Course Work and Activities

The first day of any class can be a little unsettling for both the instructors and participants. To overcome this, the summer institutes opened the course with introductions and some critical thinking puzzles. The puzzles required group interaction which served to quickly "break the ice" for the participants. After the group activity was completed, a review of the course and how to use WebCT was presented. Once the participants were familiar with WebCT, the software system used to deliver on-line courses, a pre-test was administered. The pre-test was essential because it provided a baseline of each participant's knowledge of topics that would be covered in the summer institute. After the pre-test, the engineering design process was reviewed and discussed.

The following is from the Massachusetts Science and technology/Engineering Curriculum Frameworks:

Steps of the Engineering Design Process:

1) Identify the need or problem
2) Research the need or problem
3) Develop possible solution(s).
4) Select the best possible solution(s)
5) Construct a prototype
6) Test and evaluate the solution(s)
7) Communicate the solution(s)
8) Redesign

The engineering design process was a major theme throughout the summer institutes and the participants were exposed to it throughout the classroom activities. The first key topic of the course was the basic fundamentals and theory of direct current (DC) electricity and electric circuits. Having this understanding of basic electricity is necessary before discussing alternative energy. The participants, working in pairs, were given a light bulb, battery, and wires and instructed to light up the bulb. The task itself was not difficult and the teachers did well. However, the purpose of the activity was to generate dialogue regarding electricity and some key components in electric circuits. For example, terms such as open and closed circuits, energy source and receiver (load), electric schematic, voltage, current and resistance were all discussed.

Following the simple battery and light bulb activity, a lesson plan on both Ohm's Law (V=I*R) and Watts Law (P=I*R) was completed. This lesson was supported by a demonstration using a light bulb and a power supply. The participants observed how an increase in voltage caused an increase in the amount of light being emitted by the bulb. This demonstration opened a discussion regarding Ohm's Law and Watt's Law. The teachers discovered firsthand the importance of a mathematical understanding of a science concept.

Following the Ohm's Law and Watt's Law activity, the participants built both series and parallel DC electric circuits. The hands-on lesson used both electric circuit breadboards and SNAP circuits. The teachers were exposed to the voltage and current relationships when loads are put in series and when they are put in parallel. Once again, the mathematics and equations for parallel and series circuits were emphasized. The participants were asked to put the experimental data into tables and provide graphs of voltage vs. current. Finally, the teachers were asked to build both OR and AND digital logic circuits using SNAP circuits.

The last activity for the electric circuit module was the engineering design process. The participants were asked to design and construct a series circuit using a specific voltage consuming a given power. The teachers were to test the circuit, compare it to the specification, and redesign the circuit if necessary. Finally, the design was presented with electrical schematics, calculations and test data.

After completing the material on DC electricity and its related circuits, the course turned toward the generation of alternating current (AC) and AC circuits. The participants were exposed to the fundamentals of magnetism, electromagnetism and Faraday's Law ($V_{ind} = N\, d\varphi/dt$) through PowerPoint presentation, worksheets and lab demonstrations.

Once the participants had a grasp of these fundamentals, the operation and theory of a simple AC generator was 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 was also discussed in detail. Subsequent to the generation of AC electricity, the participants were exposed to the essential concepts and terms of a sinusoidal waveform. For example, the electricity that comes out of the wall socket for most modern day homes is AC. The sinusoidal waveform is approximately $120V_{rms}$ with a frequency of 60 Hz.

It was very important for the participants to understand these basic concepts and to learn how they are related and interchanged. Therefore, terms such as: peak voltage, rms voltage ($V_{rms} = 0.707*V_p$), period (T) and frequency ($f = 1/T$) were covered. At this point in the AC activity, both Ohm's Law and Watt's Law were re-introduced with a discussion about how the laws also applied to AC circuits. The DC battery source could be replaced with an AC source in the previously covered circuits. For these resistive circuits, all the calculations would be the same except that the source would be a sine wave voltage. Sinusoidal terminology was then used in the calculation and reporting of data. This was a key connection to the previous DC activities.

The concept of energy and power was introduced after the participants had the core understanding and terminology of AC electricity. Calculations of power, energy and its relationship to household electric appliances and electronic devices were covered. The kilowatt-hour (kw-hr) was 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 was the follow up to the energy and power activity. The participants, working in pairs, were instructed to calculate "*A Modern Kitchen's Carbon Footprint.*" The teachers designed their modern kitchen by choosing and listing the electric appliances they would like to have. Their assignment was to determine the kitchen's lighting scheme and wattage of various kitchen household appliances. (A list of appliances and wattage ratings was provided). Once they knew their appliances and wattage ratings, they calculated the number of kilowatt-hours used by the entire kitchen.

Next, the participants identified the cost of electricity to run the kitchen and calculated the amount of CO_2 emitted into the atmosphere due to the energy consumption of the kitchen. Finally, the teachers were asked to propose 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 were 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 ratings of other household appliances.

Additionally, the need to limit the use of appliances to conserve energy was also discussed. The participants dedicated 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 moved 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 began with assigned readings; "Pearl Street Station: The Dawn of Commercial Electric Power" and "The War of Currents." The Pearl Street station opened in lower Manhattan, New York in September 1882. The plant opening allowed Thomas Edison to publicly present a complete direct current (DC) system of electric lighting, power and distribution. By the late 1880s, Edison's DC system was in fierce competition for supremacy with the alternating current (AC) system of electric power distribution promoted by George Westinghouse and Nikola Tesla. These readings stimulated a discussion on the two forms of electricity.

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

Water power was the next subject matter covered by the Summer Institutes. Staff from Boston's Museum of Science facilitated the day's activities, employing field-tested activities from PowerUp! and The Foundation for Water and Energy Education that they had designed previously. The first task was to provide a qualitative theory of water power usage as well as a discussion about the impact of water power historically and locally. The discussion was very productive because of the community college's location in Massachusetts within an area central to America's Industrial Revolution in the late 1800s. One of the field trips was a visit to a local hydro-electric plant near the college. The curriculum also included simple fluid mechanics, and terms such as head, flow and diameter of a pipe.

The quantitative section of the water power activity was to understand the principles of the flow equation, *[$Q = 0.62 * (\text{cross-sectional area})*(2gh)^{1/2}$].* This equation was supported with handouts and worksheets that incorporated problems for the participants to solve. Next, the teachers conducted scientific inquiry by performing the "How is Flowing Water an Energy Source?" lab. 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. The splash activity provides participants the opportunity to come to this conclusion after conducting a straightforward experiment. Next, the engineering design process was re-introduced and the teachers designed a simple water wheel. They had to build and test a prototype, and then, if necessary, redesign it to meet specifications.

Continuing with the concept of using nature as an energy source, the teachers were then exposed to wind power. Harnessing the wind to generate useful energy was discussed. Simple AC generator theory and Faraday's Law were reintroduced in this section of the course. The Museum of Science returned to the classroom to facilitate the hands-on activities. The participants constructed 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 without further modification. However, the Savonius turbine is less efficient than the more commonly seen horizontal axis wind turbines because of aerodynamics. The horizontal turbine blades are designed like airplane wings to use lift to increase the spin of 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 reinforced 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 magnets over coils of fine 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. This is a simple and efficient way to generate electricity. Also, these are the same basic principles used in almost all wind 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 teachers were 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 was increased, the teachers observed on the oscilloscope that both the induced voltage and frequency of the electricity produced by their modeled turbine had increased. 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 was 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 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.

After both the water and wind power lessons were complete, the Summer Institutes continued following the alternate energy theme by devoting a day to solar energy. Photovoltaic cells were 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 were also discussed. The participants conducted hands-on activity with some photovoltaic cells. Outside, they measured and calculated voltage, current and power of circuits with cells in parallel/series combinations. Using the data they had gathered in their solar experiments, the participants designed a photovoltaic system, using the lab PV cells, which would produce enough DC electricity to run a DC refrigerator. The refrigerator's power and voltage specifications were provided, and the design had to take into consideration the combination of parallel and series combinations. In addition, the number of PV cells and total surface area had to be calculated.

After this exercise, the class was 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 designed solar cookers. Working in pairs, the teachers designed, built and tested their solar cookers. Each group received the same amount of room temperature water and identical vessels to hold the water. Outside in the sun, the water containers were put into the solar cookers. The teachers had to observe both the time and temperature of the water. The experimental data was then graphed, and each group presented their design and data. The participants had a great time outdoors with this activity. Some of the teams also got a little competitive regarding how hot the water was getting inside their solar cookers.

Two field trips were also part of the Summer Content Institutes. In the first, the teachers visited a local hydro-electric power plant where they experienced applications of the concepts, terms and ideas that had been discussed in the class room. During the site visit, the teachers observed first hand the inside rotor of the water turbine which was being refurbished for the first time in 25 years.

The second field trip in 2006 was to a "green home" that had been off the grid since construction of the home some twenty-five years ago. This house, owned and built by one of the community college professors was powered by wind and solar (both active and passive), augmented by wood stoves. All electricity used within the home was DC as were the appliances.

The second field trip in 2007 was to the Genzyme Center which is the headquarters for the Genzyme Corporation in Cambridge, Massachusetts. This 350,000 square foot building has earned the U.S. Green Building Council’s platinum rating, the highest possible rating offered by the organization. The building uses photovoltaic solar cells to supplement electric energy, uses waste steam from a nearby power plant for cooling as well as heating, and uses extensive amounts of natural light to illuminate the building and offices. In fact, the twelve-story building has a glass exterior and a central atrium that allows natural light to enter the center. On the roof above the atrium are heliostats that help amplify the amount of natural light entering the building. Heliostats are a sophisticated system of mirrors that track the path of the sun. They reflect sunlight onto an opposing fixed set of mirrors that direct it through the atrium providing a large quantity of natural light into the center and the offices. The teachers were quite impressed with the Genzyme building, and the field trip was an effective way to conclude the Summer Institutes.

In both the 2006 and 2007 versions of the Summer Content Institutes, a section on Construction Technology and bridge structures was included in order to more closely align with the Massachusetts Curriculum Frameworks. Hands-on activities were included to support these concepts as well. Qualitatively, the ideas of forces on bridges were discussed with terms such as tension, compression, torsion, bending and shear introduced. This section also included analyzing simple structures, such as bridges and trusses. The engineering design process was once again discussed and the participants designed a basic bridge out of balsa wood. The design had to be built, tested and then, if necessary, redesigned in order to meet specifications. In the fall, some teachers were able to implement bridge design projects in their classrooms.

Fall Follow-Up Session:

The fall follow-up sessions were essential to the Summer Institutes. These sessions were dedicated to the presentations of lesson plans that the participants of the Summer Institutes developed and field tested in their classrooms. These presentations allowed for positive, constructive feedback from both peer teachers and college faculty. The following table is a list of lesson plans from 2006.

STEM Summer Content Institute-Lesson Plans 2006

Flight Paper Airplane Activity

Designing a Wind-Powered Generator
Scientific Inquiry
The Chemistry and Technological Applications of Photovoltaic Cells
Alternative Energy
The Toy Designer's Challenge
Design Shawsheen's Greenhouse
The Mathematics of Alternate Energy Systems
Perimeters and Areas
Designing a Solution
Bridges-Construction Technologies
Communicating Procedures and Results

Outside Evaluator Summary of the 2006 Institute

The following report presents the methods and findings of an evaluation conducted by Davis Square Research Associates (DSRA) in collaboration with the community college as a part of the evaluation of the 2006 Summer Content Institute Project. The report presents the data and analyses produced in the course of the 2006 Institute.

"Key findings include: 1. Participants made statistically significant pre-post gains 2. Pre-test scores were *not* predictive of post-test scores, meaning that the institute was successful with students of varying incoming levels of knowledge 3. Satisfaction survey findings were *weakly* correlated with post-test scores, indicating that the learning effects occurred regardless of the subjective responses to the institute.

Sample and Method:
The sampling frame for the survey was coextensive with the participants in the Project. The institute participants (N=13) completed a pre-test, attended the workshops, and completed a post-test (N=12). In addition, participants (N=11) completed a satisfaction exit survey at the conclusion of the institute.

All data instruments and collection were handled by institute personnel, with DSRA being contacted in August 2006 for assistance in completing the evaluation. The final satisfaction survey, as well as the pre- and post-test data, were scored by the project personnel, with the findings then sent to DSRA for analysis in SPSS.

The key questions for the survey were:

- Did the content knowledge of the participants increase over the course of the workshops?
- How did participants respond to the institute?

Effects of Participation:
Of central concern to the Project is whether participants have been able to gain in their understanding of engineering. To assess the progress of the participants, the project implemented a 33 item pre-test and a 20 item post-test. The tests were constructed by instructors from the program, with the 20 items of the post-test being repeats of items

from the pre-test. The DSRA analysis, therefore, is limited to those 20 items that appear on both pre- and post-tests.

Table 1: Gains in Engineering Content Knowledge

Test	M	% Correct
Pre-Test	11.73	59%
Post-Test	16.80*	84%

* Significant at p<.008 (Wilcoxon Signed Ranks Test)

The findings from pre-test to post-test are significant. In other words, the changes that have been measured are almost certain (99.2%) to be due to the participants having learned the content during the institute and not simply random fluctuations due to chance.

Two other considerations are worthy of note. One is the often-observed correlation between pre- and post-test, with students who do well on the pre-test also doing well on the post-test. In the case of the NECC content institute, however, the post-test scores are *negatively* correlated with the pre-test (-.112). This finding is not significant *(*p<.773), however it suggests that the instruction of the institute was highly responsive to the needs of the less-prepared teachers.
A second consideration that merits some reflection is the relationship between satisfaction and achievement. One often observes projects in which participants either like the project and does well, or they do not like the project and do poorly. In the case of the NECC project, there is almost no correlation (.063) between satisfaction (as measured by the end-of-course survey) and achievement on the post-test. What this means is that whether or not participants reported enjoying the course, they consistently and significantly gained in their engineering content knowledge.

End of Course Survey

At the end of the course, participants were given a survey that asked them to rate the instructors on a 1-5 scale, with 1 being the lowest and 5 being the highest.
Each instructor was rated for each content area, with a final instrument resulting in 21 items for the 10 days of the institute (many areas were taught by more than one instructor).

The data on the evaluation show that there was minimal variation from instructor to instructor, with the final overall evaluation score (the sum of all ratings), when averaged, resulted in the 3.8 rating, or a "Very Good" rating. This finding represents both a high and a consistent level of satisfaction with the instructors of the institute.

The open-ended responses (N=11) on the final survey can be roughly divided into two domains, one that are positive and another that offers suggestions, with the latter about twice as large as the former. The following table presents a sampling of the two

Sample of open-ended responses

Positive comments

- Excellent presentations. Group involvement. Field trips exciting, informative, and challenging—great job.

- Thank you for putting together samples of current technology, real examples that I can use in class. The course is very informative for science applications. Great job!

- Generator building was great. Water wheels also good.

- I think mixing lower + higher grades is hard--I would have benefited from seeing more labs I could use, while I think the math was beneficial to high school teachers—Thanks!

Suggestions:

- If you teach the course again, I would like a little more from my particular standards. I would specifically like more on materials and manufacturing. I am pleased that I understand electricity in a way that I never thought I could. This class was challenging—made me think. I appreciate your efforts.

- The course could benefit from a slower pace on the more advanced formulas used throughout. The course was challenging and the inclusion of hands-on model making made for an interesting summer content institute. Thank you

- Early days with lots of equations were confusing- More processing time + practice as we moved from topic to topic would be great. Also- more hands-on with the equipment would have helped me understand the concepts- (e.g.-build circuits w/bulbs, series, parallel, etc.)"[1]

Outside Evaluator Conclusions

"While the evaluation of the project is limited to the analysis of the findings submitted to DSRA from the project, yet the above data and analyses combine to create a portrait of a program that appears to be of significant benefit to the participants. Participants learned engineering content through the project and seem to have enjoyed their participation. With both new learning and a good attitude, there is an increased likelihood of the participants' classroom practices being improved."[2]

In-House Analysis of Pre-Test/Post-Test Assessment Results 2007

The following table is a compilation of the pre-test and post-test results for the participants in the Professional Development Institute of 2007 combined with the participants in the Alternate Energy for STEM Fellows course of 2007. The pre-test and Post-test items measured both knowledge of the engineering design process and knowledge of alternative energy concepts.

Name	Pre-Test Correct Out of 32 questions	Post-Test Correct Out of 32 questions	Pre-Test % Score	Post-Test % Score
Teacher1	16	24	50%	75%
Teacher2	16	26	50%	81%
Teacher3	20	18	63%	56%
Teacher4	15	21	47%	66%
Teacher5	14	18	44%	56%
Teacher6	10	26	31%	81%
Teacher7	12	23	38%	72%
Teacher8	14	21	44%	66%
Teacher9	14	17	44%	53%
Teacher10	20	31	63%	97%
Teacher11	10	28	31%	88%
Teacher12	16	21	50%	66%
Teacher13	14	25	44%	78%
Teacher14	16	22	50%	69%
Teacher15	21	24	66%	75%
Teacher16	17	21	53%	66%
Teacher17	25	30	78%	94%
Teacher18	21	19	66%	59%
Teacher19	16	23	50%	72%
Teacher20	22	24	69%	75%
# or % Correct	329	462	51%	72%

	Pre-Test	Post-Test
N	20	20
Mean	16	23
Median	16	23
Mode	16	21
Standard Deviation	3.98	3.85
T-Test: Less than .0005, so significant difference from Pre-Test to Post-Test. The difference is with almost 100% certainty due to what was learned in the class, rather than due to chance.		
Correlation: While the finding is not significant, a correlation coefficient of .13 (<.2) indicates no relationship between the Pre-Test and Post-Test scores.		

The above statistical analysis of the results was performed by the college's Office of Institutional Research. It shows that there was a significant difference from Pre-test to Post-test which was attributable to what was learned, not to chance.

Critique of Alternative Energy PD Institute of 2007

In 2007, the title of the PD institute was changed from the Science, Technology, Engineering, and Mathematics of Alternative Energy (2006) to just Alternative Energy in an attempt to appeal to more teachers. This had the unintended effect of broadening the range of abilities among the participants in both mathematics and science.

A significant problem with the content of the 2007 institute was the inclusion of construction and bridges. These topics were included in 2006 because of their presence in the middle school science and technology/engineering frameworks and left in for 2007. In hindsight, this was a mistake because it took time away from alternative energy. This mistake was compounded by the professor who taught construction and bridges. His approach was overly mathematical and not adjusted for his audience. One of his assignments was a hand-out of mathematical problems to be solved which was much too long and difficult and created significant anxiety for the participants. His failure to realize that the participants were not engineering or engineering technology students was a constant source of stress for participants and fellow instructors. In the end, his assignments played no part in the assignment of grades.

Efforts in 2007 to obtain feedback from the participants were too informal and didn't give each participant an opportunity to tell the faculty every day how he or she felt about the activities of the institute. Those instructors who did seek feedback in 2007 were able to adjust their teaching, but the process seemed much less smooth in 2007 when compared with 2006.

Daily formalized feedback would have been particularly important since there was such a spread in the participants' grade levels, mathematical comfort, and educational background. The mathematical sophistication of the middle school teachers was far, far less than that of the high school teachers and assignments should have been better modified to suit the different ability levels of the teachers. It also should have been clearer to the participants that each participant was not expected to complete all parts of an assignment. Recognizing this diversity, the institute could have made better use of differentiated instruction to model for the participants what they would have to do in their own classrooms in the fall.

Further Conclusions and Recommendations by NECC Faculty

- These professional development institutes made a significant contribution to increasing teacher-participants' knowledge of the engineering design process and of alternative energy.

- Teacher participants were able to develop lesson plans on alternative energy engineering that were appropriate to their classrooms, and aligned with the appropriate curriculum frameworks.

- The professional development course should not be considered complete and the graduate credit should not be awarded until the lesson created is implemented in the classroom, modified based upon that trial, and a final report submitted on the modified lesson.

- To present the material of alternate energy engineering to teachers who span the range from middle school to high school requires differentiated instruction on the part of the college faculty. The mathematical sophistication of the middle school teachers was often far less than that of the high school teachers and assignments had to be modified to suit the different ability levels of the teachers.

- Differentiated instruction was something with which some college faculty members had difficulty. In the future, each day's lesson and activities should be vetted by the entire instructional team to be certain they address a wide variety of participant abilities.

- A formative evaluation component should be implemented on a daily basis to insure that differentiated instruction is as effective as possible.

- The section on bridges should be eliminated (most participants scored well on the bridges portion of the pretest) to allow more time to focus on AC and additional hands-on activities.

- More hands-on activities on alternative energy like the solar cooker, solar cells and wind turbine labs should be created, activities that the teachers can bring back to the classroom.

- Develop a pre-institute questionnaire for participants on their math backgrounds, not to screen them out, but to include them in and best serve their needs.

Summary

These professional development institutes made a significant contribution to increasing teacher-participants' knowledge of the engineering design process and of alternative energy.

All teacher participants were able to develop lesson plans on alternative energy engineering that were appropriate to their classrooms, and aligned with the appropriate curriculum frameworks.

The participants were a pleasure to work with and very professional. All lesson plans were of a professional caliber. The participants who sought graduate credit each received a grade of B or better.

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Appendix

Table 1 – Description of Group Participants

Date of meeting	Number of participants	Middle School Teachers	High School Teachers	Who participated
August 13-17, 2007	7	7	0	STEM Fellows and Leaders from Public Middle Schools
July 30 – August 3, 2007 and August 6 – 10, 2007	14	7	7	Teachers from Public and Charter Middle and High Schools
July 10 – July 14, 2006 and July 17 – 21, 2006	12	7	5	Teachers from Public and Charter Middle and High Schools

Table 2 – Description of 2007 Participants' Teaching Experience

Number of Years Teaching (2007 Participants)	Percentage of Participants with that Experience
0 - 5 yrs	23.8%
6 - 10 yrs	14.3%
11 -15 yrs	19.0%
16 - 20 yrs	14.3%
21+ yrs	28.6%

Table 3 – Description of 2007 Participants by Subjects Taught

Subjects Taught All Grade Levels (6-8 and 9-12)	Percentage of Participants Teaching Subject
Math	28.6%
Physics	9.5%
Chemistry	4.8%
Technology	4.8%
Ecology	4.8%
Biology	9.5%
Health Dynamics	4.8%
Science	33.3%

Environmental Science	**9.5%**
Physical Science	**4.8%**
Space Science	**4.8%**
Earth Science	**9.5%**
Computer Science	**4.8%**
SPED	**4.8%**
Intro to Engineering	**4.8%**
Technology Education	**23.8%**

Course Description Submitted to the Graduate School for Alternative Energy Content Institute 2007

Course #: EDPS ____

Course Title:	Science and Engineering of Alternative Energy Systems
Course Credits:	3 Credits [45 Contact hours]
Instructors:	
Start Time:	9:00 am
End Time:	2:00 pm
Dates	July 30 - August 3, August 6 - August 10
Location:	Community College,

Course Description

This course is designed for middle and high school teachers to build Science and Engineering knowledge along with the associated Mathematics in the context of Alternative Energy Systems. In this course, educators will experience how Science, Engineering and Mathematics are used to understand, to analyze and to design small-scale Alternative Energy Systems employing hydroelectric power, wind turbines, and solar energy and they will be helped to locate the Science and Technology/Engineering topics within the Massachusetts Curriculum Frameworks so that curriculum maps may be developed along with specific scope and sequence charts.

Objectives: Teacher-participants will be able to

- explain the science, technology, engineering and/or mathematical topics listed in the following Topical Syllabus;
- demonstrate the application of the topics to Alternative energy systems;
- specify which standard(s) of the Massachusetts Curriculum Frameworks for Science and Technology/Engineering and/or Mathematics is/are addressed by each of the above;
- Design, field-test and modify a written lesson plan that references the supporting science and/or engineering topics, the associated mathematics, and the application of the topic(s) to alternative energy systems. The developed lesson shall include hands-on activities and pre- and post- assessments of student learning.

Dates:

10 Sessions	9:00am--2:00 pm		
1	**July**	**30**	Critical Thinking, the Engineering Design Process, WebCT
2		**31**	DC Electric Circuits
3	**August**	**1**	Generating Ac and AC Electric Circuits
4		**2**	Storing and Distributing Electricity
5		**3**	Water Power
6		**6**	Construction Technology, Bridges, Structures
7		**7**	Wind Power
8		**8**	Small-scale Hydroelectric Power, Solar Energy
9		**9**	Green Home Technology
10		**10**	Site Visit to a Green Building

Topical Syllabus:

Topics	Activities	Day Number
Critical Thinking, Engineering Design, WebCT	Pretest Critical Thinking Puzzle Lab: Light Bulb Experiment Design Process: AND/OR Logic Circuits Using WebCT	1
DC Electric Circuits	Understanding the Theory: Qualitatively--The Nature of Electricity Current, Voltage, Resistance Power and Energy Continuity in circuits Series and Parallel electric circuits Quantitatively (Mathematically)-- Ohm's law: $V = I \times R$ Watt's Law: $P = V \times I$ Representing Data with Tables and Graphs The Engineering Design Process:	2

	Design, using a specified voltage, a resistive circuit consuming a given power Construct the designed circuit Test the circuit and compare to specifications Redesign if necessary Present the design including schematic diagram and test data	
AC Generation and AC Circuits	Understanding the Theory: Qualitatively Magnetism and Electromagnetism Lenz's Law Faraday's Law Simple AC generator theory, the effect of # of poles, # of turns, and angular velocity of the turbine Alternating current electricity and sine waves (frequency, period, amplitude) Ohm's Law and Watts Law for AC. RMS or effective value. Capacitors, inductors and transformers. Quantitatively (Mathematically)— Faraday's Law, $V_{ind} = N (d\varphi/dt)$ $I_c = C (dv/dt)$ $I_v = L (di/dt)$ Ohm's law: $V = I \times R$ Watt's Law: $P = V \times I$ $V_{rms} = 0.707 V_P$ Analyzing and Predicting: Lab: Measuring current and voltage in simple AC circuits containing inductors, capacitors, resistors or a combination of elements; measuring amplitude, frequency and period of AC voltages and currents; presenting and explaining data; analyzing results Calculations: power, energy, energy use, kilowatt hours, wattage-ratings of appliances, household wiring (blowing a fuse and tripping a circuit breaker) The Design Process: Design a kitchen by selecting appliances and then specifying the circuits required to supply power to the appliances. Predict the energy requirement for the kitchen and estimate the cost per month. Present the design including appropriate diagrams and predicted cost of operation.	3

Storing and Distributing Electricity	Understanding the Theory: Qualitatively Distribution, Transmission Lines Mutual Inductance & Transformers Rectification Power Supplies Capacitor filters. Quantitatively (Mathematically)— Transformers: turns ratio (n) = N_{sec}/N_{pri} $V_{sec} = n\ (V_{pri})$ $P_{pri} = P_{sec}$ $V_{pri}\ I_{pri} = V_{sec}\ I_{sec}$ $I_{sec} = (1/n)\ I_{pri}$ Step-up and Step-down transformers Power Supplies Half-Wave Rectifiers: $V_{AVG} = V_{P(out)} / \pi$ Full-Wave Rectifiers: $V_{AVG} = 2V_{P(out)} / \pi$ $V_{rms} = 0.707\ V_P$ Analyzing and Predicting: Lab: Measuring voltage and current in circuits with multiple voltage sources of different frequencies. Synchronizing generators on the grid. Using MultiSim The Design Process: Rectification: AC to DC conversion, power supplies, and battery chargers Lab: Design a simple power supply, build a prototype, test prototype, redesign if necessary to meet specifications. Present the design including appropriate diagrams	4
Water Power	Understanding the Theory: Qualitatively Water power use, locally and historically Simple fluid mechanics (head, flow, diameter of a pipe) Quantitatively (Mathematically)— Flow: $Q= 0.62*(area)*[2gh]^{1/2}$ Equations of fluid mechanics Analyzing and Predicting: Fluid Flow – Handout with examples.	5

	Worksheet for participants with problems Lab: How is Flowing Water an Energy Source? Activity A Will water falling twice as high create a splash twice as large? An activity for middle school students from The Foundation for Water and Energy Education. In this activity participants will conduct scientific inquiry, will observe and understand the potential energy of falling water, will analyze data by averaging and will communicate data by graphing results. The Design Process: Design a simple water wheel, build a prototype, test prototype, redesign if necessary to meet specifications. Present the design including appropriate diagrams.	
Construction Technology, Bridges, Structures	Understanding the Theory: Qualitatively • Structures for wind and water powered generation of electricity • Bridges: tension, compression, torsion, bending, and shear Quantitatively (Mathematically)— $F = ma$ Analyzing and Predicting: • Lab: Analyzing simple structures, such as bridges and trusses The Design Process: Lab: Design a simple structure, build a prototype, test prototype, redesign if necessary to meet specifications. Bridges made from pasta (Civil Engineering Activity #2 from *Teaching Engineering Made Easy*, pp. 173-179) Bridges made from balsa wood	6
Wind Power	Understanding the Theory: Qualitatively Power and Energy from Wind Simple AC generator theory, the effect of # of poles, # of turns, and angular velocity of the turbine. Quantitatively (Mathematically)— Faraday's Law, $V_{ind} = N (d\varphi/dt)$ Magnetic Flux, $\Phi = F_m / \mathbf{R}$ Magnetomotive force, $F_m = NI$ f = (#of pole pairs)(rps)	7

	Power in the area swept by a wind turbine rotor: **P = 0.5 x rho x A x V^3** ***Wind Turbine Power:*** **P = 0.5 x rho x A x Cp x V^3 x Ng x Nb** Analyzing and Predicting: Calculating power and energy from wind. Lab: How is wind an Energy Source? Activity A Construction of a wind generator based upon the Savonius design. Participants will build and test a wind generator. Lab information is located at http://www.re-energy.ca/ Analyzing and Predicting: Lab: Observe the electrical output via an oscilloscope of a small model wind turbine. Predict and observe both the frequency and amplitude of the electrical signal when the angular velocity of the wind turbine blades are increased and decreased. Calculations: frequency, period, amplitude (rms, peak and peak-to-peak) of an electrical signal.	
Small-scale Hydroelectric Power, Geothermal Energy	Concept: Hydroelectric Power and Geothermal Energy - Site visit to a small hydroelectric plant and geothermal mill building. Understanding the Theory: Qualitatively Heat and energy Method of Energy Conversion and Heat transfer Quantitatively (Mathematically) Hydroelectric gross energy expected: P = eHQg where: P = Electric Power Output in kilowatts (kW) e = Efficiency range 0.50 to 0.90 (50% to 90%) H = Head, in meters (m) Q = Design flow, in cubic meters/sec (m^3/s) g = acceleration of gravity, normally 9.81 m/s^2	8

	For small-scale hydroelectric applications, if an Efficiency value of 81% is assumed, the following equation can be used: e x g = .81 x 9.81 = 7.95 $P\ (kW) = 7.95 \times H\ (m) \times Q\ (m^3/s)$ Ohm's law: V = I x R Watt's Law: P = V x I Maximum power point (the maximum output electrical power, $V_{max} \times I_{max}$; or P_m, in Watts). DC Appliance Ratings Analyzing and Predicting Lab: Handouts and calculations for Power Output. The Design Process: Web enhanced and paper design of a small hydroelectric plant.	
Solar Power and Green Home Technology	Understanding the Theory: Qualitatively—Green Home Technology • Method of Energy Conversion (Transformation) • Heat transfer • Types of Technologies o Solar PV Cells, Modules, Panels and Arrays (PV Systems) o Solar Heating Systems The Design Process: Design Lab: DC refrigerator specifications for voltage, current, and power. Solar cell specs: 0.8x1.6inch (2.4cm) cell delivers about 0.3-amps at 0.55VDC in full sunlight Design a series/parallel combination circuit of solar cells to meet the above specifications for the DC refrigerator. How much total surface area does this design require? How many football fields would this require?	9
Green Building Site Visit Post-test and Post-survey	**Genzyme Corporation** 500 Kendall Street Cambridge, MA 02142	10

Course Requirements and Determination of Final Grade

Assignments – 60%

Worksheets and design projects reinforcing mathematics, science, and engineering concepts must be submitted.
Short written summaries relating topics from this course, Science and Engineering of Alternative Energy Systems, to the Massachusetts Curriculum Frameworks must be submitted.

Final Project – 20%

A final project must be submitted of a lesson developed by the teacher which is appropriate for use in his or her own classroom.
The classroom lesson must include a written lesson plan that references the supporting science and/or engineering topics; the associated mathematics and the application of the topic(s) to alternative energy systems; hands-on activities; and pre- and post- assessments of student learning.
The developed lesson must include a curriculum map and a lesson-specific scope and sequence chart to illustrate how their lesson(s) will be integrated into the existing scope and sequence guides of the teacher's school district. The lesson must include the appropriate Standards of the Massachusetts Curriculum Frameworks which it addresses.

Presentation of a Report on Final Project – 20%

An in-person presentation of a report of the final project (classroom lesson) as tested in the teacher's classroom along with suggested modifications to the lesson must be made in addition to the written form of the revised classroom lesson.

References:

1. Faux, R. (2006). Evaluation of the NECC Content Institute: Evaluation Report. Somerville, MA: Davis Square Research Associates.

2. Faux, R. (2007). Evaluation of the NECC STEMS Summer Content Program: Interim Report. Somerville, MA: Davis Square Research Associates.