AC 2007-1635: EXPERIENCE WITH AN ALTERNATIVE ENERGY WORKSHOP FOR MIDDLE SCHOOL SCIENCE TEACHERS

R. Mark Nelms, Auburn University

Regina Halpin, Program Evaluation and Assessment

Experience with an Alternative Energy Workshop for Middle School Science Teachers

Encouraging interest in science and engineering can begin early in the education process if teachers have the proper training[1]. Discussed in this paper is an outreach activity for middle school science teachers to provide them with the curriculum materials needed to foster students' interest in science and engineering. This activity was a workshop focused on alternative energy, which has received much attention recently. Alternative energy sources are not based on fossil fuels; solar, wind, and wave energy are examples of alternative energies. President Bush proposed the Advanced Energy Initiative in his 2006 State of the Union address to reduce the nation's dependence on foreign oil imports. Two parts of the Advanced Energy Initiative are concerned with solar energy and hydrogen fuel cells.

The study of solar energy and hydrogen fuel cells can be facilitated with the fuel cell car kit available from Thames & Kosmos (www.thamesandkosmos.com). This kit contains both a solar panel and a fuel cell. Also included in this kit is an experiment manual containing a number of experiments which can be performed with the solar panel and fuel cell. This manual formed the basis for a number of the hands-on activities performed by the teachers. Each teacher received a fuel cell car kit for participating in the workshop. The car was assembled before the workshop; therefore, workshop time was not devoted to the assembly of the car. The development of the workshop materials was guided by the National Science Teachers Association teaching standards[2] and the Alabama Science and Math Curriculum Standards[3] for middle school teachers. The national science teaching standards supported by the National Science Teachers Association were produced by the National Research Council[4] in 1995 and published in 1996. The workshop activities alternated between lectures and hands-on activities. It was considered essential for the teachers to perform hands-on activities so that they would be comfortable enough with the materials to employ them in the classroom[5]. Copies of all workshop handouts were given to the teachers at the end of the workshop for them to use in their classrooms. Two workshops were conducted in the summer of 2006. The first workshop was held June 27-28, 2006 and was attended by 15 teachers. The second workshop was held July 18-19, 2006 and was attended by 14 teachers. Described in this paper are the activities associated with the two-day workshop and the integration of national and state science curriculum standards, the summative workshop evaluations, and the follow-up results of how the 29 teachers have integrated the activities into their classroom activities.

The workshop format implemented was lecture immediately followed by appropriate hands-on activities that allowed the teachers to better understand how to apply the engineering concepts presented. The content for the workshop was selected based on the national and state middle school science curriculum standards. The first day of the two-day workshop began with a discussion about global energy usage and its relation to economic development around the world. Alternative energy sources were also identified. The next session started with energy, the Law of Conservation of Energy, and some of the different forms of energy – mechanical, chemical, electrical, thermal, nuclear, etc. This laid the foundation for the introduction of basic electrical concepts such as voltage, current, resistance, and power. The use of a multimeter to measure voltage, current, and resistance was presented next. Safety aspects of using a multimeter in electric circuits was also presented. The first hands-on activity period followed. The teachers were grouped into small teams of 2-3 people; each group was provided with D-cell batteries, resistors, and cables with alligator clips. Using the multimeter contained in the fuel cell car kit, the teachers measured resistance of the various resistors and the voltage of the batteries. Simple circuits were constructed, and measurements of voltage and current were made with the multimeter. Finally, each group was given a potentiometer, or variable resistor, to use as a load for the battery. A circuit was constructed to measure the voltage across and the current flowing through the potentiometer. The groups were asked to measure the voltage and current for five different settings on the potentiometer. After the measurements were made, the groups made a plot of the current flowing through the load versus the voltage across the load. This plot is referred to as *i-v* curve. The morning session ended with a discussion of the *i-v* curves measured by the different groups.

The afternoon session of the first day started with a presentation on solar cells. Basic principles of solar cell operation were discussed. Common solar cell terminology such as open-circuit voltage and short-circuit current were defined. The *i-v* (current vs. voltage) and P-V (power vs. voltage) curves for a solar cell were described. Examination of the P-V curve led to the concept of the maximum power point for a solar panel and the idea of maximizing the power output from solar panel by employing a maximum power point tracker. The effect of varying solar intensity on the *i-v* curve was illustrated. The ideas of direct and diffuse solar radiation and how to measure each of these were presented. In addition, measurement of the solar radiation reflected from the ground was discussed.

For the afternoon hands-on activities, the groups were given the cars from the kits, which were configured for operation from the solar panel provided in the kit. A number of tasks were assigned.

1) Measure the *i-v* curve for the solar panel in the kit using the multimeter and potentiometer from the morning hands-on session. The groups were subdivided into 4 categories: north, south east, and west. For each subdivision, the i-v curve was measured with the solar panel facing the direction assigned. For example, the north groups made measurements with their solar panel facing due north.
2) Measure the impact of the angle of inclination of the solar panel with respect to the sun. The open-circuit voltage of the solar panel was measured with the multimeter and the angle of inclination was measured using a protractor.
3) Measure the direct and diffuse solar radiation as discussed earlier in the afternoon. Again, the open-circuit voltage of the solar panel was measured with the multimeter and utilized to examine the amount of direct and diffuse solar radiation.
4) Measure the amount of solar radiation reflected from the ground. Again, the open-circuit voltage was utilized to study how much solar radiation is reflected from the ground.
5) Hook up the electric motor on the car and operate the car on solar power.

After the afternoon tasks were completed, the teachers reconvened and discussed their results and how the content could be integrated into their middle school classroom instruction. This was an essential part of our workshop model because all teachers are held accountable for the content presented in the classroom based on the national and state science curriculum standards.

Therefore, teachers seem more likely to integrate the engineering concepts into their curriculum if they are shown how the content meets the curriculum standards. The approach used to accomplish this task was for the teachers to use a checklist to evaluate how well the workshop activities could be integrated into their middle school curriculum. This exercise began with the teachers using the National Science Teachers Association Content Standards for Grades 5-8[2]. Their task was to select each standard that was met based on the content and hands-on activities they had experienced that day and to give specific examples of how each standard was met. Even though Standard C was not met based on the workshop content, notes were given to the teachers to indicate how they could meet this standard if they chose to expand the workshop content into areas of how energy related to photosynthesis and plant life. This portion of the workshop is important for faculty or professional development coordinators responsible for planning teaching training that involves engineering concepts to include in their programmatic design. Even though the teachers were aware during the workshop that they were "doing" science, it is essential to provide the teachers an opportunity to discover for themselves how the teaching standards are applicable to their own teaching and classroom methods. Faculty planning to implement a similar workshop should note that the programmatic design should start with the appropriate teaching standards and the content should be selected to align with the standards; not the reverse. The curriculum standards checklist used for the curriculum standard integration portion of this workshop is given below.

NSTA Content Standards, Grades 5 – 8[2]

Standard A: Science as Inquiry

___Abilities necessary to do scientific inquiry
___Understandings about scientific inquiry

Standard B: Physical Science

___Physical and chemical properties/changes of matter
___Motions and forces (electrical forces)
___Distinguish between potential and kinetic energy
___Transfer of energy (electricity)
___Law of conservation of energy

Standard C: Life Science (could include energy related to photosynthesis and plants)

Standard D: Earth and Space Science

___Explain use of sources of energy in the Earth system (solar radiation for energy)

Standard E: Science and Technology

___Abilities of technological designs
___Understandings about science and technology

Standard F: Science in Personal and Social Perspectives

___Science and technology in society

Standard G: History and Nature of Science

___Nature of science

By using this checklist, the teachers discovered that the engineering concepts relating to alternative energy met their science curriculum standards. Furthermore, this exercise led the teachers into a discussion of other ways they could use the activities including science fair projects, challenging activities for the advanced or gifted student, and grant proposals.

The next step was for the teachers to use a checklist of the Basic and Advanced Scientific Process and Application Skills as outlined in the Alabama Science Course of Study[3] to evaluate how well the alternative energy content and hands-on activities met these standards. Because of the complexity of the engineering concepts being presented, it was important for the teachers to realize that some prior knowledge for the student was essential for a successful lesson. Therefore, two questions were added to the checklist relating to the prior math and science knowledge and technology skills the students would need to be prepared to do. This information was also used by the teachers to brainstorm how connections to real-world conditions could be made using the alternative energy concepts in their classroom instruction. The checklist used for this evaluation by the teachers is given in Figures 1 & 2.

SKILL	**HOW SKILL WAS MET IN ACTIVITY**	**DESCRIPTION OF SKILL FROM STANDARDS**	
Observing		Using one or more of the senses to gather information about one's environment; data collection	**BASIC**
Communicating		Conveying oral or written information verbally as well as visually through models, tables, charts, and graphs, using questioning, correcting misunderstandings	
Classifying		Utilizing simple groupings of objects or events based on common properties	
Measuring		Using appropriate metric units for measuring length, volume, and mass	
Predicting		Proposing possible results or outcomes of future events based on observations and inferences drawn from previous events	
Inferring		Constructing an interpretation or explanation based on information gathered	

What prior science/math knowledge would your students need to complete this activity?
List the use of technology-enhanced activities to solve problems or evaluate data.

Figure 1. Basic Scientific Process and Application Sskills

SKILL	HOW SKILL WAS MET IN ACTIVITY	DESCRIPTION OF SKILL FROM STANDARDS	
Controlling Variables		Recognizing the many factors that affect the outcome of events and understanding their relationships to each other whereby one factor (variable) can be manipulated while others are controlled	ADVANCED
Defining Operationally		Stating definitions of objects or events based on observable characteristics	
Formulating Hypotheses		Making predictions of future events based on manipulation of variables	
Experimenting (Controlled)		Conducting scientific investigations systematically, including identifying and framing the **question** carefully, forming a **hypothesis**, managing **variables** effectively, developing a logical experimental **procedure**, recording and analyzing **data**, and presenting **conclusions** based on investigation and previous research	
Analyzing Data		Using collected data to accept or reject hypotheses	

CONNECTIONS: According to the Alabama Science Course of Study, previous learning is reinforced through application to real-world conditions rather than abstract situations. Learning is an integrated, ongoing process rather than isolated fragments of knowledge remembered for a test. How were CONNECTIONS made in the activity you completed?

Figure 2. Advanced Scientific Process and Application Skills

For the morning session of the second workshop day, the teachers were divided into two groups. One group went to the Auburn University Solar House shown in Figure 3. This house was constructed for the 2002 Solar Decathlon competition held in Washington D.C. by the US Department of Energy. The operation of the electrical system in the solar house was described and related to the ideas and concepts presented on the first day of the workshop. The solar house was utilized as a platform to discuss energy efficiency in the design and construction of residential dwellings. A second group convened in a computer laboratory to discuss weather data. A real-time weather web site (http://www.wunderground.com/) was accessed to examine weather data and a web site through which weather data from the AU Solar House was viewed and comparisons were made. The use of this weather data in the classroom was discussed as related to solar energy. The teachers were given two activities that required them to utilize the real-time weather data provided via the Internet. During this portion of the workshop, the teachers were given the Alabama math and language arts curriculum standards as a reference to determine how the weather and energy-related concepts were interdisciplinary and could be team-taught. At the midpoint of the morning session, the two groups exchanged locations so that both groups had the opportunity to view the solar house and learn how to integrate weather-related activities with the alternative energy concepts. The teachers discovered from these activities that the topic of weather, which is familiar to all students, was an interesting introduction to the more complex alternative energy concepts. Furthermore, they were able to learn how to integrate language arts into their lesson plans by completing open-ended activities that required writing explanations and descriptions using the weather and energy data from the Internet. This led into a discussion of how the content was interdisciplinary.

Figure 3. The Auburn University Solar House

Summative Workshop Assessment

On the last day of the workshop, each participant completed an evaluation as a summative assessment of the workshop format and content. The results are given in Tables 1 – 5. The results in Table 1 are the average ratings on a scale of 1 (not involved) to 4 (very involved) from the 29 workshop participants on how actively they were involved in the workshop. Many of the results were reflective of the basic and advanced process and application skills in Figure 1 & 2 used by the teachers to evaluate the content. Furthermore, the teachers reported a 4.0/4.0 on how well the content connected to the science curriculum standards and a 3.96/4.0 on expanding their knowledge in the area of alternative energy. This was encouraging that the teachers were confident in their preparation to implement the content into their classroom instruction.

Table 1. Teachers' Average Rating of Workshop Involvement

Workshop Activity	Ave.
Investigating phenomena that can be studied scientifically	3.96
Collecting data	4.00
Using inquiry processes to solve problems	3.88
Interpreting results	3.92
Making sense of findings through reflection and discussion	3.92
Addressing issues, events, problems significant to science	3.85
Building on prior and current science understandings and abilities in the content area	3.85
Collaborating with others to solve a problem in a team effort	3.96
Integrating new knowledge into science classroom teaching	3.96
Connecting science to real-world aspects relating to the content presented	3.96
Expanding my knowledge in the content area presented	3.96
Connecting the content presented to the NSTA and Alabama Curriculum Standards	4.00

The results in Table 2 are the participants' average rating on a scale of 1 (disagree) to 4 (strongly agree) of how relevant the alternative energy concepts were for their classroom instruction. Overall, the teachers reported that they were confident teaching the content (3.58/4.0) and that the workshop met their expectations (3.96/4.0). Throughout the evaluation, the teachers reported that the content presented was relevant to their classroom teaching and met the national and state science curriculum standards.

Table 2. Average rating on a scale of 1 (disagree) to 4 (strongly agree) from the 29 workshop participants on the workshop content:

Workshop Content	Ave.
I feel confident teaching this content to my middle school students as a result of this workshop	3.58
The content and activities on Current and Voltage are relevant to my classroom teaching	3.38
The content and activities on Solar Cells are relevant to my classroom teaching	3.69
The content and activities on Weather are relevant to my classroom teaching	3.50
The content and activities on Fuel Cells are relevant to my classroom teaching	3.42
The content and activities on Energy are relevant to my classroom teaching	3.73
I will use the solar car and related activities in my classroom teaching	3.77
I would attend this workshop again or recommend it to a colleague	4.00
The content was well connected to the national and state curriculum standards	3.85
I will integrate into my science lesson plans the activities presented and provided in this workshop	3.65
I feel I need more training in this content area before I can teach it to my middle school students	2.73
The content of this workshop met my expectations.	3.96

Table 3. How to improve the workshop:

COMMENT	FREQUENCY
Longer time frame; more days or hours per day	5
Provide closer parking facilities	3
Nothing; Excellent workshop; fun and interacting	3
We should have tested H2 and O2.	1
Use calculators for complex math. Using graphing calculators or graphing software for one of the graphs.	1
On day 1, perhaps a bit more of an overview of what the course will involve	1
Simplify some of the reading material in the book	1
Spend about 30 minutes on basic circuits	1
Race the cars after configuration.	1

Table 4. Activities Liked Best

COMMENT	FREQUENCY
Solar/Fuel Cell car activities	10
Electrolysis	6
Solar House	5
Real-life weather comparisons on the web	4
Using the multi-meter	3
Hands-on activities	2
Solar collection information on the first day	1
Electrolysis with the salt water and paper clips	1
Measurement sessions	1
Electrical and power formulas	1
Graphing	1
Showing how math and science relate with weather	1
Basic energy and alternative energy sources	1

Table 5. Activities Liked Least

COMMENT	FREQUENCY
None. Liked them all	8
Graphing	3
Electrolysis too complicated for kids (and me)	1
Chemistry aspects of lesson was confusing	1
None. Great job. So much information and materials send home with us.	1
Thank you for viewing some of the workshop from a teacher's perspective.	1
One of the best workshops I have attended.	1
Great workshop!	1
It was interesting and a lot of fun	1
It would be beneficial if participants received the booklet or at least a synopsis of the activity content prior to day 1.	1

In Table 3, the participants reported helpful suggestions for improving the workshop. Their favorite activities involved using the solar/fuel cell car (Table 4), which was the focus of the workshop. Overall, the teachers enjoyed all the activities (Table 5).

Follow-up Assessment of Classroom Implementation

According to the assessment results of the workshop as reported by the participants, the workshop model implemented using the alternative energy concepts was a success. However, the follow-up assessment question to answer was whether the teachers actually implemented the material in their classroom instruction. As a follow-up evaluation, each of the participants were emailed 6 months after attending the workshop and asked the following questions: (1) Are you integrating the engineering concepts into your curriculum? Explain., (2) How are you using the hands-on activities?, (3) What other ways are you using the workshop materials with middle school students or for professional development? (4) How have you been accountable for integrating the alternative energy material into your curriculum?

Of the 29 participants, 18 responded. Of those 18, three indicated they had not integrated any of the materials nor used any of the hands-on activities. One of those three participants explained that she would implement the material during the second half of the school year because that is when she would cover appropriate material in the curriculum. Of the remaining 15, 7 reported integrating the concepts as part of a 6-9 week unit, two used the materials to develop their own 2-3 week lesson plan to teach the concepts, and 6 integrated isolated concepts into their curriculum for 2-5 days when appropriate. All of the 15 teachers reported that they had used the hands-on activities as they integrated the engineering concepts and one teacher reported using them as challenging activities as well. Other than for instructional purposes, 5 of the teachers reported using the materials for other purposes. One teacher responded to a grant proposal to purchase additional fuel cell cars and materials for his classroom, two teachers have students working on science fair projects relating to the alternative energy concepts, and three teachers have conducted professional development workshops at their school for their fellow math and science teachers. As for accountability, all of the teachers reported their lesson plans were reflective of the state science curriculum standards and those teachers who conducted professional development workshops used the curriculum checklists as well. In summary, 52% of the participants implemented in their classroom the materials presented during this workshop. This supports the positive results from the summative workshop evaluation and confirms the necessity to include accountability measures in future workshop models. These follow-up results reinforce the conclusions stated previously regarding programmatic design for other faculty or professional development coordinators using engineering concepts. Any faculty responsible for planning teaching training should use the appropriate science teaching standards to guide the content in an effort to increase teachers' use of the material in their own classroom. The teachers should be guided in discussions of how the content can be used for extracurricular student activities or as a foundation for their own professional development (e.g. grants). Finally, the integration of the math and language arts teaching standards should be integrated and interdisciplinary concepts should be emphasized.

References

1. Wiggins, G. P. and McTighe, J. (2005). Understanding by Design: Association for Supervision and Curriculum Development, Alexandria, VA.

2. National Science Teachers Association teaching standards, http://www.nsta.org/standards.

3. Alabama Science and Math Curriculum Standards, http://www.alsde.edu/html/home.asp.

4. National Research Council, http://www.nationalacademies.org/nrc.

5. Daniels, H. and Bizar M. (1998). Methods that Matter: Stenhouse, York, ME.