University Energy Education Curriculum Project: Infusing Energy Education throughout Science Teacher Education

J. Scott Townsend
Eastern Kentucky University
scott.townsend@eku.edu

William Bennett
Eastern Kentucky University
william.bennett@eku.edu

Melinda Wilder
Eastern Kentucky University
melinda.wilder@eku.edu

Presented at ASTE annual conference
Clearwater Beach, FL
January 6, 2012
ABSTRACT

In the past decade, energy conservation and independence has re-emerged as a national concern. It is vitally important that students have a conceptual understanding of energy and how their choices affect these issues on local, national, and global scales. Appropriate preservice and inservice teacher professional development needs to be in place before effective energy education can be implemented in schools. Interestingly, there is very little recent research on effective energy programs for teachers, thus posing a challenge for science and environmental teacher educators. This presentation will outline the scope, sequence, and evaluation results of a year-long energy education curriculum initiative at a regional state university. Our goal was to infuse energy topics throughout an existing preservice and inservice curriculum in order to improve the knowledge and attitudes of teachers as well as their ability to implement effective energy education in their K-12 classrooms. This comprehensive program can serve as a model for other universities in designing their own energy education professional development programs. In addition, the data generated by the various assessments may serve as a first step in updating research findings in energy education.
Introduction

In the past decade, energy conservation and independence has re-emerged as a national concern. It is vitally important that students have a conceptual understanding of energy and how their choices affect these issues on local, national, and global scales. Toward that goal, many states are beginning to infuse energy education into their K-12 curricula. In spring 2011, U.S. Department of Energy Secretary, Steven Chu; U.S. Department of Education Secretary, Arne Duncan; and Francis Eberle, Executive Director of the National Science Teachers Association (NSTA) presented *America’s Home Energy Education Challenge*, a new energy education program. This initiative is designed to educate students about energy efficiency, and how to play an active role in their families’ energy use (USDOE, 2011).

Appropriate preservice and inservice teacher professional development needs to be in place before effective energy education can be implemented in schools. Interestingly, there is very little recent research on effective energy programs for teachers, thus posing a challenge for science and environmental teacher educators. Much of the available information dates back to the 1970-80’s. The limited current research focuses on attitudes toward energy conservation or specific energy sources. A Greek study found that despite teachers’ knowledge about and attitudes toward renewable energy sources, there was no indication that these teachers influenced their students’ opinions concerning energy sources (Liarakou, Gavrilakis, & Flouri, 2009). A relevant study from 1983 indicated found that teachers who participated in a summer energy institute were more likely to incorporate energy education topics into their curriculum (Bitner-Corvin, 1983). Another dated study found that a one day workshop could result in positive changes in teachers’ attitudes toward energy activities (Dunlop & Fazio, 1981). There seems to be an urgent need for new programs and updated research in energy education regarding both awareness and action.
The Project

This paper will outline the scope, sequence, and evaluation results of a year-long energy education curriculum initiative at a regional state university. Our goal was to infuse energy topics throughout our existing preservice and inservice curriculum in such a way that not only would the knowledge and attitudes of teachers be impacted, but also their ability to implement effective energy education in their K-12 classrooms would be enhanced. Consequently, this program consisted of six components in order to reach a variety of both preservice and inservice teachers in diverse ways. The components included (1) integration of energy as a theme throughout elementary, middle, and secondary science methods courses, (2) an energy unit for an environmental issues course, (3) an energy focused environmental service learning course, (4) a MA-level energy content course, (5) NEED Project energy education workshops; and (6) dissemination of resulting products at both the state and national levels.

Through the implementation and evaluation of these six components, we found these curricular changes can help address both the problem of effective energy education programs and begin to address the lack of recent energy education research. Preliminary findings indicate that several components increase teachers’ energy awareness as measured by a pre/post survey developed for and used throughout the entire project. Energy content knowledge was measured using the Energy Concept Inventory (Swackhamer & Dukerich, 2003) and other appropriate assessments. Each particular component had a limited number of participants. Consequently, any type of analysis other than basic descriptive statistics was not be appropriate.

Panelist A: Energy Education and Environmental Service Learning
Service Learning as Pedagogy was a course developed using energy as the primary focus for an environmental service learning project. The course used the Earth Force service learning curriculum to model classroom activities while simultaneously designing and implementing an energy project throughout an entire semester. Earth Force engages young people as active citizens to improve the environment and their communities. Through Earth Force, students get hands-on, real-world opportunities to practice civic skills, acquire and understand environmental knowledge, and develop the skills and motivation to become life-long leaders in addressing environmental issues. This program also helps increase knowledge and interest in STEM disciplines. Earth Force achieves these results by training and supporting educators as they implement a unique six-step model for engaging young people. Thanks to rigorous evaluation, Earth Force has documented that the model positions young people to use their creativity and passion to play a meaningful role in environmental decision-making. The Earth Force environmental service learning model is flexible and can be used in a variety of settings including a club, an elective class, a component of a science or social studies class or as a part of a self-contained classroom teacher’s activities.

**Participants**

This class was offered as a split level course in hopes of involving both preservice and inservice teachers, the final composition of the students consisted of ten inservice teachers, and two Master of Arts in Teaching (MAT) students. Partial tuition reimbursements were offered to practicing teachers in order to recruit a diverse group of class participants. The ten practicing teachers were four middle school science, one middle school agriculture, one middle school language arts, one middle school Personal Achievement School Success (PASS) coach, one fifth grade math, and two fourth grade elementary teachers.
Course Format

The format for the course was one campus meeting per week from 5:30 pm – 8:15 pm. The first two hours of the class were devoted to modeling class activities from each of the six steps of the Earth Force process that would replicate two class periods in a normal school setting. The last 45 minutes of class was devoted to discussing how those activities would look in their classrooms and how the activities might be modified to fit each teacher’s curriculum needs.

Course Project

The class participants chose Maywoods Environmental Education Laboratory as their community for their energy service learning project. Maywoods is a 1,500 acre nature preserve that is owned and managed by Eastern Kentucky University. Many of the inservice teachers who were in the class have either participated in summer classes offered at the facility or have taken their students there on a field trip during the school year. The overall goal of the project was to focus on best practices for energy efficiency and promote energy awareness in the community of Maywoods. The class decided that they wanted to create a policy that the buildings at Maywoods undergo an energy use audit every five years. Research revealed that there was not a policy in place and the class constructed a letter to the Director of the Division of Natural Areas asking that the policy be adopted. This was achieved in short order, and the students moved on to other priorities. An energy audit was conducted by a certified energy auditor with help from the class. The main criteria used by the participants for improvements were a large return on investment in a short amount of time. After the audit was completed the following recommendations were submitted for action.

- Replace all incandescent light bulbs with CFL bulbs.
- Replace dishwasher with an energy star appliance.
- Install weather stripping and caulk around doors and windows.
- Purchase recycling containers.

Due to delays in receiving the energy audit report, as well as University regulations on changes to facilities, the recommendations were forwarded to the appropriate channels and funding for the suggested changes were secured through grant monies.

**Evaluation**

This course was evaluated using pre/post energy awareness surveys, evaluation of weekly reflection questions including a final reflective essay covering the entire project, an Earth Days presentation to the University on the project, and final service learning action plan scores.

**Results**

Table 1 indicates the results for the pre/post energy awareness survey. All elements measured increased over the semester with attitudes increasing the post. The energy awareness survey can be found at [http://www.naturalareas.eku.edu/uenergyed.php](http://www.naturalareas.eku.edu/uenergyed.php)
Table 1: EMG707, Service Learning as Pedagogy Pre/Post Energy Awareness Survey Results (n=12)

Results from the final reflection essays demonstrated the following:

- 83% of students reported making energy conservation efforts in their personal lives and that they had influenced family members, students and coworkers, by modeling best practices for conserving energy
- 83% reported that they thought the “process” was valuable as a learning /teaching tool
- 100% of students reported that the course will help them professionally

Due to the collaborative nature of the class, the results indicated in Table 2 indicate all class participants contributed a successful service learning project. In addition, the data indicate they were able to translate their learning experience into a plan for a practical application in their own classrooms.

Table 2: EMG 707, Service Learning as Pedagogy, Energy related assignment scores
Panelist B: Energy Education and Curriculum Integration

Energy education was integrated into existing courses in two ways. First, energy-related modules were incorporated into an MA-level environmental issues course, a requirement in the environmental education endorsement program. These modules were designed to enable teachers to critically analyze the stakeholders, values, and beliefs regarding energy issues as well as demonstrate teaching strategies that engage K-12 students.

Course Format

Since this class was offered to inservice teachers throughout the University’s rural service region, class participants were given a choice of formats that work best for their schedule. This year the students chose to meet every other week on campus and participate in online assignments during the off weeks. During the campus class meetings, teachers participated in a variety of class activities focusing on the science of energy, alternative fuel possibilities and the realities of coal production. These activities were designed to teach the energy content as well as to model activities they could use in their classrooms. For the online portion of the class, students were required to participate in discussions based on a wide variety of readings. These readings included state and national energy policy, research on energy use behaviors as well as information into the efficacy of various traditional and alternative fuel sources. These readings were then used as a basis for issue investigation jigsaw assignments.

Participants

The course had 11 participants including two high school science teachers, two middle school science teachers, one middle school social studies teacher, one middle school agriculture teacher, one middle school Personal Achievement School Success (PASS) coach, and three middle grades Master of Arts in Teaching with science and social studies emphasis students.
Evaluation

Evaluation of these units occurred in three ways. First, the pre/post survey determined the effectiveness of these modules in raising energy awareness. Content knowledge was assessed through the use of concept maps and a debate assignment (Is coal to liquid is a viable way meeting the increased energy needs? or Should biodiesel be the focus of Kentucky’s renewable energy program?). This assignment required both a verbal and written portion. Inservice teachers were required to teach energy education lessons in their own classroom and collect resultant student work to analyze the effectiveness of their instruction.

Results

Results from each of the components are found in Tables 3 and 4. These data do provide an indication of the impact of the integrated energy curriculum. The results from the energy awareness survey are mixed with a slight increase in attitudes, awareness, behavior and motivation and a decrease in knowledge. This is somewhat contradicted by the other measures since it appears that the students did learn the content as evidenced by the concept map and debate scores. The scores on the teaching assignment seem to indicate that their ability to implement effective energy education lessons was also limited.
Table 3: CNM 800, Environmental Issues Pre/Post Energy Awareness Survey Results (n=11)

<table>
<thead>
<tr>
<th>Assignment</th>
<th>Mean (%)</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concept Map (Energy)</td>
<td>90.0</td>
<td>0.63</td>
</tr>
<tr>
<td>Concept Map (Coal)</td>
<td>90.0</td>
<td>0.62</td>
</tr>
<tr>
<td>Lesson Plan and Evaluation</td>
<td>78.7</td>
<td>25.7</td>
</tr>
<tr>
<td>Debate</td>
<td>96.7</td>
<td>3.85</td>
</tr>
</tbody>
</table>

Table 4: CNM 800, Environmental Issues, Energy related assignment scores (n = 11)

Course Format

The second avenue of integration was the use of an energy theme throughout all levels of science methods courses. This thematic approach included using energy related topics and activities to demonstrate a variety of teaching strategies including discrepant events, conceptual change activities, inquiry based learning and analysis of socio-scientific issues. Table 5 shows the various teaching strategies were taught using specific energy topics.
<table>
<thead>
<tr>
<th>Teaching topic</th>
<th>Energy related resource</th>
<th>Energy content</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mirrors, <em>Minds of our Own</em></td>
<td>Light energy</td>
</tr>
<tr>
<td>Discrepant events</td>
<td>Ice Melting Blocks, Education Innovations</td>
<td>Heat and thermal energy</td>
</tr>
<tr>
<td>Levels of Inquiry</td>
<td>Roller Coasters, CPO Science</td>
<td>Energy transformations, potential and kinetic energy</td>
</tr>
<tr>
<td></td>
<td>Foam Roller Coasters</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Film canister rockets</td>
<td>Chemical energy</td>
</tr>
<tr>
<td></td>
<td>Sounds All Around</td>
<td>Sound energy</td>
</tr>
<tr>
<td></td>
<td>Convection Currents, <em>Convection: A Current Event</em>, GEMS, Lawrence Hall of Science</td>
<td>Convection</td>
</tr>
</tbody>
</table>

Table 5: Teaching topics and associated energy integration activities

The elementary, middle, and secondary methods courses followed a fairly traditional format in that they met on a regular basis on campus with a significant field experience component (>30 hours of classroom experiences). The elementary and middle grades science methods were taught in a block with other courses included other content methods classes, a curriculum class and a content reading class. These block classes were designed to model the integration of best practices in elementary or middle school. The secondary methods class was offered as a weekly night class so MAT students with temporary provisional certification could participate.

**Participants**

The elementary science methods classes consisted of 74 preservice elementary teachers. The middle grades class had 23 participants, all of which had science as one of their two content emphasis areas. Their other area was either language arts, mathematics or social studies. The secondary class consisted of only seven students—two were temporary provisionally certified teachers with one teaching ninth grade chemistry and the other teaching biology; four were
traditional undergraduate earth science teaching majors; and the other participant was a MAT biology emphasis.

Evaluation

The effects of the thematic approach to the science methods courses will be evaluated using the pre/post energy awareness survey, a pre/post energy content knowledge assessment, and a questionnaire to determine if energy education activities were implemented during their student teaching experience. Due to the timing of these courses, data are not currently available.

Panelist C: Energy Education Content Knowledge Course: “Energy as a Unifying Concept for Science Teaching

Another component of the University Energy Education Curriculum Project was to design a MA-level course specifically focused on middle grades level content-specific aspects of energy. The resulting course was designed in a hybrid format consisting of six weekly onsite class meetings supplemented by online assignments. The primary purpose of the hybrid format was to make it more accessible to teachers who lived or worked in the outlying areas of the University’s service region in rural central Appalachia. Tuition reimbursements were used as a recruiting tool for inservice teachers to immerse more teachers in energy education.

Course Format

This course focused on middle level content-specific aspects of energy including energy types, transfer of energy, work, force, conservation, efficiency, and several other areas of importance. These concepts were addressed onsite by using various inquiry energy activities pertaining to content the teachers would be able to use in their own classrooms as well as activities that challenged their own content knowledge. The class met onsite at the University for six consecutive Fridays for 4.5 hours each session. These meetings were supplemented by
weekly online assignments using teacher professional development videos by Annenberg Media (2002) that focused on energy content and students’ perceptions of energy. In addition to the weekly online videos, course participants answered content and reflection questions about the content in the videos, were assigned readings pertaining to energy content, and took weekly content quizzes addressing concepts from the videos, the readings, and the onsite classroom activities. See Appendix 1.

Participants

The course had 13 participants from several different backgrounds. Three were elementary certified; three were full time middle grades MAT with science emphasis; four were middle grades MAT temporary provisionally certified science teachers, one middle grades MAT provisionally certified social studies teacher, one inservice middle grades mathematics teacher and one middle grades language arts teacher seeking science certification.

Evaluation

The course was evaluated using the pre/post test, a modified version of the Energy Concept Inventory (Swackhamer & Dukerich, 2003) that included blank space between questions that required the participants to explain their multiple choice answers for each item in writing so a more accurate assessment of conceptual understanding could be scored. Less formal evaluations were used throughout the course included weekly quizzes related to course activities and content, weekly video questions, and classroom prompts. The energy awareness survey was also given in the pre/post format, but the results are not included in this paper.

Results

As shown in Table 6, every student in the course made gains in their content knowledge measured on the Energy Concept Inventory. The average score on the 30-question pre-test was a
36%. At the end of the course, the overall class average on the post-test was 81% with an overall class increase of 45%.

Table 6: Energy Concept Inventory results

<table>
<thead>
<tr>
<th>Pseudo</th>
<th>Pre-Score (30)</th>
<th>Pre-Percentage</th>
<th>Post-Score (30)</th>
<th>Post-Percentage</th>
<th>Difference%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steve</td>
<td>10</td>
<td>0.33</td>
<td>27</td>
<td>0.90</td>
<td>0.57</td>
</tr>
<tr>
<td>Natalie</td>
<td>16</td>
<td>0.53</td>
<td>24</td>
<td>0.80</td>
<td>0.27</td>
</tr>
<tr>
<td>Sherry</td>
<td>11</td>
<td>0.37</td>
<td>24</td>
<td>0.80</td>
<td>0.43</td>
</tr>
<tr>
<td>Katy</td>
<td>9</td>
<td>0.30</td>
<td>22</td>
<td>0.73</td>
<td>0.43</td>
</tr>
<tr>
<td>Charlie</td>
<td>10</td>
<td>0.33</td>
<td>21</td>
<td>0.70</td>
<td>0.37</td>
</tr>
<tr>
<td>Gwen</td>
<td>4</td>
<td>0.13</td>
<td>28</td>
<td>0.93</td>
<td>0.80</td>
</tr>
<tr>
<td>Anita</td>
<td>7</td>
<td>0.23</td>
<td>25</td>
<td>0.83</td>
<td>0.60</td>
</tr>
<tr>
<td>Sheila</td>
<td>4</td>
<td>0.13</td>
<td>17</td>
<td>0.57</td>
<td>0.43</td>
</tr>
<tr>
<td>Jonathon</td>
<td>18</td>
<td>0.60</td>
<td>25</td>
<td>0.83</td>
<td>0.23</td>
</tr>
<tr>
<td>Jerry</td>
<td>14</td>
<td>0.47</td>
<td>25</td>
<td>0.83</td>
<td>0.37</td>
</tr>
<tr>
<td>Jesse</td>
<td>11</td>
<td>0.37</td>
<td>26</td>
<td>0.87</td>
<td>0.50</td>
</tr>
<tr>
<td>Fannie</td>
<td>8</td>
<td>0.27</td>
<td>24</td>
<td>0.80</td>
<td>0.53</td>
</tr>
<tr>
<td>Freddie</td>
<td>20</td>
<td>0.67</td>
<td>29</td>
<td>0.97</td>
<td>0.30</td>
</tr>
</tbody>
</table>

Table 6: Energy Concept Inventory results

Several of the questions on the Energy Concept Inventory exemplify the increase in the students’ understanding of important energy concepts. For example, Question 33 below is difficult for the test-taker because the idea of a refrigerator in a room could possibly cause him to think of the room cooling down. However, the students on the pretest didn’t conceptualize the idea of the room as a closed system (theoretically) with only electrical energy coming into the room, therefore adding energy to the room that would ultimately increase the heat of the room. Figure 1 shows the number of students who got the question correct on both the pre and post-tests. One student’s responses are used from both her pre/post tests to show a change in the understanding of the concept.
Throughout the course, there was a focus on the concept of “energy as part of a system,” specifically focusing on identifying the system for which one is defining. Question 6 (Figure 2) shows another question that was difficult for the teachers during the pre-test with only two out of thirteen getting the answer correct. However, after taking the post-test, all thirteen participants got the question correct. Even though the question wasn’t used specifically in the course, the students keyed in on the bolded, underlined phrase of “earth and box.”
Overall, every class participant made an increase with the lowest pretest score of 13% and a high pre-test score of 67%. The post-test scores showed increases, from low to high, of 57% to 97%. The instructor in this course found this to be significant because the students did not see the test at any point during the course. They only saw it the week before class started when they signed up for times to come take the test. However, some of the test questions were used during the weeks of the course for quiz questions, but only if they fit specifically with the content covered that week during class, the professional development videos, or the reflection/content questions accompanying the videos.

Conclusion

Our goal as stated above had the following elements

1. To infuse energy topics throughout our existing preservice and inservice curriculum
2. Impact the knowledge and attitudes of teachers and
3. Increase their ability to implement effective energy education in their K-12 classrooms
By redesigning the science methods courses to include an energy theme, we met the goal of infusing energy topics throughout our existing elementary preservice curriculum and the preservice curriculum for middle grades and secondary science teachers. The two new courses, Service Learning as Pedagogy and Energy as an Unifying Concept in Science Teaching as well as the use of energy related modules in the current environmental issues class offered a variety of ways to reach inservice teachers. These three courses were targeted primarily at inservice science teachers at all grade levels. Consequently, our inservice audience was somewhat limited.

Our impact on the knowledge and attitudes of teachers based on data collected have shown mixed results. The knowledge related measures—Energy Concept Inventory, concept maps and debate assignment, all indicated an general increase. The attitude related information—energy awareness survey and reflection essays—provide different information depending on which class was involved. This could be related to the type of class and the amount of time spent on energy related topics. For example, in the environmental issues class, three energy related modules were incorporated over a six week period. Items from the energy awareness survey were not necessarily directly addressed in any of this instruction. In the service learning class, the entire semester focused on energy and a specific energy related service learning project developed and implemented by the students. Again, items from the awareness survey were not directly addressed but students were more involved with the energy project.

The increase in the class participants’ ability to implement effective energy education in their classrooms also has mixed results from the limited data. Data from the service learning course indicates that inservice teachers can develop effective plans to conduct energy related service learning in their classrooms. But evidence from the environmental issues class suggests that these class participants are less effective in executing an energy related lesson.
The energy education aspect of this endeavor has continued through the fall 2011 semester. The service learning and environmental issues courses will be offered in spring 2012 and plans are to continue with energy aspects of the elementary, middle school, and secondary methods courses. In addition, the Energy as a Unifying Concept in Science Teaching course will be offered every other summer to preservice and inservice middle school teachers. Examples of assignments from all project components can be found at http://www.naturalareas.eku.edu/uenergyed.php. Professional development outreach pertaining to energy education, such as the NEED Project for preservice elementary teachers will continue on a semester-by-semester basis. More data will to be collected in order to search for trends or patterns in effective energy education strategies.
References


Appendix 1

EMG 807: Energy as a Unifying Concept in Science Teaching
Weekly topic and online video descriptions (two weekly videos are utilized during the week following the in-class activities):

Science in Focus: Energy (www.learner.org)
Understanding the concept of energy is crucial to the comprehension of many ideas in physical science, Earth and space science, and life science. The video programs, print guide, and Web site of this workshop for elementary school teachers provide a solid foundation, enabling you to distinguish between the way "energy" is commonly understood and its meaning in science. Examine energy’s role in motion, machines, food, the human body, and the universe as a whole. Learn how energy can be converted from one form to another and transferred over space and time. And explore the notion of "conservation of energy" — the idea that energy can neither be created nor destroyed. Return to the classroom with a new focus on the important concept of energy.

Class 1:
What Is Energy?
Interviews about energy with children, scientists, and people on the street reveal the wide range of concepts that teachers encounter. In this session, you will look at the differences between the everyday language of energy and the scientific concept, see highlights of its history, and learn its importance in our understanding of the world.

Force and Work
Scientists define energy as the ability to do work. In this session, see how work is defined in physics and examine how energy and work are related.

Class 2:
Transfer and Conversion of Energy
Change happens when energy is transferred or converted. In this session, examine conversion between potential and kinetic energy. Through examples, see how events that involve a small amount of energy can trigger much larger events.

Energy in Cycles
Energy can be seen in cycles every day, from the bouncing of balls to the swinging of pendulums. In this session, further explore the relationship between kinetic and potential energy to understand how cycles begin and are sustained, and why they decay.

Class 3:
Energy in Food
All life forms use energy. In this session, explore the transfer and conversion of the potential energy in food, and see how that energy is stored. Through animations, witness photosynthesis, the process by which plant cells capture the ultimate energy source for all food — sunlight.

Energy Flow in Communities
Communities are populations of organisms that live and interact together. The structure of a community is defined by food web interactions. The process of energy flow is the focus of this session as the interactions between producers, consumers, and decomposers are examined.
Class 4:
Energy and Systems
Physicists use the concept of a system to trace and quantify the flow of energy. In this session, take a close look at a number of energy systems and see how this concept is closely linked to the Law of Conservation of Energy.

Heat, Work, and Efficiency
A machine's energy output cannot be greater than its input. In this session, look at the energy that goes into useful work, examine how some always ends up as heat, and see why systems are never 100% efficient.

Class 5:
Understanding Energy
Energy lights our homes, fuels our transportation systems, and much more, but affordable energy is in limited supply. In this session, look at the global impact of these limits and see how being smart about using energy will become more important in our daily lives.

Class 6:
NEED Project (National Energy Education Development Project) 6-hour teacher workshop