Topics in Energy and the Environment: Opinions and Evaluations of the Classroom Experience
Jessica L. Anderson, Rose-Hulman Institute of Technology

Abstract
This paper describes an elective course for teaching energy and the environment from an engineering perspective. One goal of this course was well stated by Hyde and Karney, "Environmental education for engineering students is intended to make them better environmental citizens."[1] In addition, Splitt stated that “a fundamental change in engineering education [is] required to help the next generation of engineers learn to design for sustainable development and long-range competitiveness”.[2] Therefore, in addition to describing efforts in teaching this course, this study examines students’ overall perceptions of the energy and environment challenges as they relate to engineering and how their perceptions have changed due to this course. This course is presented in a multi-media, active learning, project-based environment which increases the student’s basic knowledge of a wide breath of energy/environmental topics. These topics included many fossil fuel-based technologies such as combustion of coal, oil, and natural gas, mitigation of carbon dioxide and other fossil fuel combustion byproducts such as carbon capture and sequestration, and renewable or carbon-free energy sources such as wind energy, wave and tidal energies, solar energy, biomass, nuclear, and hydrogen. Other topics included carbon balances, energy balances, and climate modeling for the Earth.

The winter quarter of the 2007-2008 school year is the first year a course like this has been taught at Rose-Hulman. Therefore, it is very important to become familiar with the successes and failures of this course as it was taught. Additionally, it is important to assess student learning not only in their group discussions, quizzes and projects, but also in their perception of energy and the environment. The class was composed of a mixture of juniors and seniors, with one graduate student, in several engineering majors including chemical engineering, civil engineering, and engineering management. A total of 19 students took the course in this it’s first offering.

Key Words
Engineering Curricula
Topics in Energy and the Environment: Opinions and Evaluations of the Classroom Experience

Jessica L. Anderson, Department of Chemical Engineering, Rose-Hulman Institute of Technology

Introduction

This paper describes an elective course for teaching energy and the environment from an engineering perspective. One goal of this course was well stated by Hyde and Karney, “Environmental education for engineering students is intended to make them better environmental citizens.”[1] In addition, Splitt stated that “a fundamental change in engineering education [is] required to help the next generation of engineers learn to design for sustainable development and long-range competitiveness”.[2] Therefore, in addition to describing efforts in teaching this course, this study examines students’ overall perceptions of the energy and environment challenges as they relate to engineering and how their perceptions have changed due to this course. This course is presented in a multi-media, active learning, project-based environment which increases the student’s basic knowledge of a wide breath of energy/environmental topics. These topics included many fossil fuel-based technologies such as combustion of coal, oil, and natural gas, mitigation of carbon dioxide and other fossil fuel combustion byproducts such as carbon capture and sequestration, and renewable or carbon-free energy sources such as wind energy, wave and tidal energies, solar energy, biomass, nuclear, and hydrogen. Other topics included carbon balances, energy balances, and climate modeling for the Earth.

The winter quarter of the 2007-2008 school year is the first year a course like this has been taught at Rose-Hulman. Therefore, it is very important to become familiar with the successes and failures of this course as it was taught. Additionally, it is important to assess student learning not only in their group discussions, quizzes and projects, but also in their perception of energy and the environment. The class was composed of a mixture of juniors and seniors, with one graduate student, in several engineering majors including chemical engineering, civil engineering, and engineering management. A total of 19 students took the course in this its first offering.

Course Development

The overall goal of this course was to provide the students enough information about the various energy sources and their impacts on the environment to enable the students to form their own opinions of the subjects, in effect creating an “understanding of the impact of technology on the health of the environment.”[3] These goals were accomplished in many ways. First of all, the class was presented in a power-point lecture format which pulled information from many sources. The power-point lecture format not only allowed for a lot of information
to be transmitted in a relatively short time frame but also allowed for easy transitions to and from different media and internet sources, as the computer was already connected to the classroom media system. Examples of alternate media sources include animations from company websites on a particular technology or concept, protests over technologies or their impacts presented on YouTube, a news broadcast that highlighted a particular subject, etc. I find that these alternate sources often have a large impact on the students not only because it is presented in a video format (they don’t have to take my word for it), but also because they relate to the ‘real-world’ examples of companies and groups affected by these energy/environment impacts.

Secondly, many class readings were assigned on various topics to provide additional information that the lectures did not or could not provide. This material was meant to supplement facts and opinions presented in class and also to provide additional resources and opinions. Therefore, the readings varied in sources from articles in magazines such as Chemical and Engineering News or Chemical Engineering Progress, to refereed journal articles, to news media articles on popular opinions, etc.

During each class period, sufficient time was allowed for class discussion on the lecture and readings for a given topic. This discussion time allowed students to not only ask questions, but also express their opinions on the subject to their classmates, thus adding an additional dimension to the topics. On one occasion, the entire class period was devoted to a class debate on the subject of biomass. The class was divided into two teams; one side argued towards using land for biomass as food, and the other towards using land for biomass for energy. They were given a week for which to research and prepare their arguments, then an entire class period to state their findings. In particular, the students came away with the different perceptions about the subject and the arguments which ensue.

The student’s learning assessment came somewhat from homework and quizzes, but largely from a research project on a topic of their choice. This project was a quarter-long project with several smaller milestones during the quarter, culminating in an oral presentation given to all members of the class and a written report on their findings. The project topics were generally chosen in areas not fully covered in the lecture or in additional areas which were related in some fashion to the class focus. Some examples include anaerobic digestion (using waste products towards methane generation), nuclear fusion – the ITER project (as opposed to nuclear fission handled in class), energy sources for developing nations (renewable vs. nonrenewable), etc. At the completion of these projects their presentations were assessed by their classmates and the group members evaluated their team work.

**Evaluations/Findings**
This course was offered as an environmental elective. As such, the students taking the course had some initial interest in the topic, whether professional or merely inquisitive. Overall, many engineering students are not interested in becoming environmental professionals. Yet, as Hyde and Karney state “their work, and the work of their communities of practice, may have a profound effect on the environment.”[1] This is especially true for the chemical and civil engineering students in this class. As there were no fundamental equations or other basic knowledge that was mandatory to be conveyed as per the student’s major requirements, assessment of this course is largely opinion-based. As such, an end-of-course survey was prepared to gather some information on how this class may or may not have changed their opinions, as well as their general knowledge about the subject. In the future, it is recommended that in addition to the survey at the end of the course, a preliminary survey be given at the beginning of class to obtain a better idea of their initial opinions and base-knowledge about the topics covered. This will allow a more accurate assessment of the learning achieved throughout the quarter and allow the faculty to evolve the course towards areas that may require additional attention.

Survey participation was completely voluntary, and 32% of the students chose to participate. The survey consisted of several opinion-based questions on a scale ranging from ‘strongly agree’ to ‘strongly disagree’ or ‘very likely’ to ‘very unlikely’. Question topics asked on this scale consisted of the student’s opinions for their understanding of global climate change and energy needs, their own carbon footprint, the school and city’s environmental consciousness, and their ability to express energy views to others who did not attend the course. Additional questions were not given a scale of assessment but rather students were asked to comment on the various topics covered in the course. An example of the questions for comment include listing things they felt that Rose-Hulman could do to reduce its energy consumption, and listing advantages/disadvantages to fossil fuel use and its future. A full copy of the survey is available in the supplemental information.

Results from the survey are summarized below. Figure 1 summarizes the student responses for questions relating to course material. Specifically these questions refer to their understanding of climate change and current and future energy needs and supplies. As shown, of the students who chose to partake in the survey, most felt that the course aided in their understanding of these subjects.
In addition, the students were asked to comment on the lessons learned through listing several advantages and disadvantages of the course topics. The course topics were grouped into five separate topics, including carbon capture/sequestration, carbon free energy sources, Earth balances, fossil fuel use, and renewable energies. This information can be used to loosely determine how well some of the information was learned. The results are summarized in Table 1. Overall, of the students polled, the majority of the issues associated with these topics were listed and fairly complete.

Table 1: Summarized student responses when asked for advantages and disadvantages to several class topics

<table>
<thead>
<tr>
<th>Topic</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon capture/sequestration</td>
<td>• Lowered greenhouse gas emissions</td>
<td>• Questions about the permanence of storage: not enough known about long-term environmental affects, technology largely unproven</td>
</tr>
<tr>
<td></td>
<td>• Ability for continued fossil fuel use and enhanced fossil fuel recovery</td>
<td>• Expense of the technology</td>
</tr>
<tr>
<td></td>
<td>• Long-term storage</td>
<td>• Overall sustainability</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon free energy sources (Hydrogen, nuclear)</td>
<td>• Ability to generate large (currently needed) amounts of energy</td>
<td>• Nuclear waste/environmentally hazardous storage</td>
</tr>
<tr>
<td></td>
<td>• Avoids harmful greenhouse gas emissions</td>
<td>• Safety concerns/public perception</td>
</tr>
<tr>
<td></td>
<td>• Energy is safe and abundant</td>
<td>• Expense of building more nuclear power plants</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Hydrogen only energy carrier</td>
</tr>
<tr>
<td>Earth balances (modeling, carbon cycle, energy cycle)</td>
<td>Ability to have some predictive power for changing events</td>
<td>Inaccuracies in model prediction</td>
</tr>
<tr>
<td>-----------------------------------------------------</td>
<td>---------------------------------------------------------</td>
<td>--------------------------------</td>
</tr>
<tr>
<td>Possible demonstrations on where current actions may lead</td>
<td>Ability to assess potential climate solutions</td>
<td>Only short-term accurate predictions</td>
</tr>
<tr>
<td>Ability to assess potential climate solutions</td>
<td>Can help determine how climate changes are related</td>
<td>Mathematical models cannot predict everything</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fossil fuel use</th>
<th>Can provide energy needed now and far into future</th>
<th>Pollution (greenhouse gases)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Readily proved technologies</td>
<td></td>
<td>National security, importation from foreign sources/political issues with trade and transport</td>
</tr>
<tr>
<td>Cheap and abundant fuel resources</td>
<td></td>
<td>Non-renewable resources/unsustainable</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Environmental damage from obtaining fuels</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Renewable energies (wind, tide, wave, hydropower, solar)</th>
<th>Small steps towards sustainable future</th>
<th>Lack of large energy supply/cannot meet current needs</th>
</tr>
</thead>
<tbody>
<tr>
<td>High resource potentials</td>
<td>Reduced or negligible emissions/clean energy source</td>
<td>Not much support from government</td>
</tr>
<tr>
<td>Reduced or negligible emissions/clean energy source</td>
<td>Endless resource supply</td>
<td>Still developing technologies/expensive</td>
</tr>
<tr>
<td>Endless resource supply</td>
<td>Less reliance on foreign countries for fuel</td>
<td>Non-continuity of some resources such as wind and solar (at night)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>More public awareness to meet sustainable goals</td>
</tr>
</tbody>
</table>

When asked about their personal consumption of energy, 2/3 of the students agreed that as a result of this course, they felt more incentive to change their personal energy consumption. The remaining 1/3 of the students disagreed, meaning they felt no more incentive to change their personal energy consumption than before taking this course. When asked to comment on how they plan to change their energy consumption this year, most responses included conservation; turning off lights and unplugging unused electronics, such as their laptops, and reducing shower times. Some comments also included finding alternative methods of energy to reduce their carbon footprint.

Figure 2 summarizes the student’s attitudes towards Terre Haute, IN (city where Rose-Hulman is located) and Indiana’s fossil fuel use. In general, the student’s felt that Terre Haute was not very concerned with the environment. They also had mixed opinions on whether or not fossil fuel use should be continued in Indiana. An additional question related to this topic included the students’ opinion
on the ‘greenness’ of Rose-Hulman. The results stated that Rose-Hulman’s greenness was ‘fair’ to ‘good’ with 67% of the students choosing ‘fair’.

The questions for comment on the survey about this topic are questions 15 and 16. Question 15 asked about what Rose-Hulman could change about its energy use. Results included basic conservation, i.e. turning off lights when not in use (adding sensors or timers for the classrooms). In addition, they felt that Rose-Hulman could be more conscientious about the temperatures in the building, both during the day and at night, along with seasonal variations (making sure the rooms aren’t too hot in the winter, or cool in the summer). They also suggested making Rose-Hulman students more aware of their energy use, i.e. electronics not in use, especially during the night hours.

Question 16 asked about additional energy sources that could be utilized for Indiana’s future energy needs. The responses included solar energy, nuclear energy, biofuels, and increased/continued IGCC use. By mentioning IGCC, this may also provide insight into the mixed fossil fuel responses in Figure 2. Some of the high sulfur coal and pet coke being used as a fuel for generating electricity in this area is gasified in one of the country’s two working Integrated Gasification Combined Cycle (IGCC) plants – the Wabash River Energy, Ltd. The gasification process dramatically reduces the amount of harmful emissions and harmful waste by-products produced as compared to the normal combustion process with these fuels. Therefore, in essence, Indiana is using ‘clean coal’ technology and many believe they can continue fossil fuel use for this reason. By far, the most responses in this area were for nuclear energy, which illustrates the changing opinion towards nuclear energy in America, especially in younger generations.

Additionally, the students were asked about how they view their peers and their ability to express opinions of energy and the environment towards their peers due to this course. Figure 3 summarizes these results. In general, the results
state that this course may have slightly increased the student’s likelihood of speaking with their peers about their energy consumption and increased many of their abilities to express their own opinions on energy topics.

When asked to comment on how the course influenced their thinking about energy and the climate, there were many responses given, with all comments shown in Table 2. These survey results indicate that a broad-based course such as this one can influence a student’s thinking not only towards their own consumption, but also towards their future careers. In addition, the students were asked if they would include ‘green thinking’ (meaning birth-to-death resource thinking) in their engineering problem solving and technical skills. 100% of the students agreed that they would incorporate green thinking into their problem solving. This is also demonstrated above in Table 2. If no other result is seen from this course, hopefully this impact will be realized in the future of our engineers.

![Figure 3: Questions 10 and 11 from survey](image)

- "How likely are you to talk to others about their energy consumption/carbon footprint"
- "Compared to your peers, please rate your ability to express your views of energy and the climate."

Figure 3: Questions 10 and 11 from survey
Table 2: Question 27 from the course survey.

<table>
<thead>
<tr>
<th>Briefly describe how this course influenced your thinking about energy and the climate.</th>
</tr>
</thead>
<tbody>
<tr>
<td>• “It opened my eyes to all of the technologies available and what is actually viable.”</td>
</tr>
<tr>
<td>• “The course provided a lot of broad information to expand my understanding of current energy issues as well as introduced me to a lot of different material that could be focused upon in other lectures or interests in a career field.”</td>
</tr>
<tr>
<td>• “I do not feel that my personal life is going to change – I’m not going to dedicate myself to studying algae or put solar panels on my house. However, now that I have a general understanding of a lot of the technologies, I will definitely be ready to suggest green engineering projects in my future career if it can save the company money.”</td>
</tr>
<tr>
<td>• “This course helped me to form my own opinions about energy and the climate. It has helped me become more aware about what’s going on around me.”</td>
</tr>
<tr>
<td>• “This course has influenced me to be more involved in understanding, developing, and encouraging others to learn more about renewable sources of energy. This knowledge will definitely effect my professional knowledge and skills in the work force.”</td>
</tr>
</tbody>
</table>

Finally, students were polled about their opinions on whether the federal government should do more to encourage renewable or more sustainable energy sources. 100% of the students polled agreed that the federal government should do more, with 50% of them strongly agreeing. This is a major result from these students, as this course was designed to be as unbiased as possible, with students being allowed to make up their own opinions about energy.

Conclusions

Overall, this paper has demonstrated that the students came away with the general knowledge needed to form their own opinions about energy and the environment. As the first time a course like this has been offered at Rose-Hulman, there were a large number of students interested in taking this course. Continuing this offering could lead to a much broader student contribution not only to their personal energy consumption, but towards making Rose-Hulman a more environmentally friendly institution and also impacting the engineering field in general as they begin their industrial or academic careers.

Bibliography


Supplemental Information
The Energy and Environment Course Survey is presented here as it was presented to the students, in its entirety.

The information gained from this survey will allow us to estimate the opinions of the class regarding energy and by your own account, if your opinions have changed in any way due to taking this course. It also verifies that you have taken some knowledge from the class about energy needs and supplies, both currently and in the future, for the world and in particular for the U.S. In addition we are looking for your opinion on the greenness of Rose-Hulman and Indiana and your assessment of some changes that could be made. Your participation in this survey is required for the class; however, your participation in the data analysis and publication is voluntary. Your responses will be confidential and all data will be reported in aggregate. There are no known risks from participating in this survey. If you have any questions about your rights in this survey, please contact Bob Throne (812) 877-8414 or throne@rose-hulman.edu.

Begin Energy & Environment Course Survey

1. I acknowledge that I have been informed of and understand the nature of and purpose of this survey and freely consent to allow the results to be analyzed confidentially for use in this study.

2. As a result of this course, I have a better understanding of climate change (interactions between energy sources and environmental impact).
   - [ ] Strongly Agree
   - [ ] Agree
   - [ ] Disagree
   - [ ] Strongly Disagree

3. As a result of this course, I have a better understanding of current world energy needs.
   - [ ] Strongly Agree
   - [ ] Agree
   - [ ] Disagree
   - [ ] Strongly Disagree

4. As a result of this course, I have a better understanding of future world energy supplies.
5. As a result of this course, I feel more incentive to change my personal energy consumption and/or carbon footprint.

- Strongly Agree
- Agree
- Disagree
- Strongly Disagree

6. The general population in Terre Haute is concerned about the environment.

- Strongly Agree
- Agree
- Disagree
- Strongly Disagree

7. The federal government should do more to encourage renewable or more sustainable energy sources.

- Strongly Agree
- Agree
- Disagree
- Strongly Disagree

8. Fossil fuel use should be continued in Indiana.

- Strongly Agree
- Agree
- Disagree
- Strongly Disagree

9. How likely are you to include ‘birth-to-death’ green thinking into your engineering
problem solving/technical skills?

  □ Very Likely
  □ Likely
  □ Unlikely
  □ Very Unlikely

10. How likely are you to talk to others about their energy consumption/carbon footprint?

  □ Very Likely
  □ Likely
  □ Unlikely
  □ Very Unlikely

11. Compared to your peers, please rate your ability to express your views of energy and the climate.

  □ Much Better
  □ Better
  □ About the Same
  □ Worse
  □ Much Worse

12. Please rate the ‘greenness’ of Rose-Hulman.

  □ Very Good
  □ Good
  □ Fair
  □ Poor
  □ Very Poor

13. Which of the following topics had the most influence on your opinion of energy and/or climate change?

  □ Carbon capture/sequestration
  □ Carbon free energy (nuclear, hydrogen)
Earth balances (modeling, carbon cycle, energy)
Fossil fuels
Renewable energy

14. List 3 things you plan to change about your energy consumption this year.

15. List 3 things you feel that Rose-Hulman can do to reduce its energy consumption this year.

16. List 3 plausible energy sources given the geologic location of Indiana for Indiana’s Future.

Please state 3 advantages to each of the energy sources/carriers covered in this course.

17. Carbon capture/sequestration

18. Carbon free energy (nuclear, hydrogen)
19. Earth balances (modeling, carbon cycle, energy)

20. Fossil fuels

21. Renewable energy

Please state 3 disadvantages to each of the energy sources/carriers covered in this course.

22. Carbon capture/sequestration

23. Carbon free energy (nuclear, hydrogen)
24. Earth balances (modeling, carbon cycle, energy)

25. Fossil fuels

26. Renewable energy

27. Briefly describe how this course influenced your thinking about energy and the climate.