Session 2533

Incorporation of an Energy Conservation Theme into Thermal Science Courses

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I. Introduction

This paper describes how I wove the theme of energy conservation into two engineering science classes, Thermodynamics I and Heat Transfer. I believed that teaching these courses with a theme would not only liven up the material for the students, but also present an opportunity for me as the instructor to become more aware of contemporary energy conservation issues. Additionally, I have taught these classes for about 10 years now and felt the theme incorporation would be a good way to renew my own enthusiasm for the material.

Young and Stuart[1] discuss how teaching with a unifying theme (in their case, a plant trip) can improve student learning. They demonstrated how a theme can facilitate connections between topics, increase appreciation for the practical applications of concepts, and enhance retrieval of information in later courses. In addition, they discuss how a "theme course" can generate enthusiasm for engineering and provide a vehicle for consideration of environmental, economic, and ethical issues. If a student is motivated to learn, and remains motivated, the chances for significant learning are increased. Manteufel[2] observes that "students can be motivated by introducing life-affecting applications early and repeatedly in the class."

The objectives for the theme incorporation were to:

- increase student appreciation for the importance of energy conservation
- experiment with open-ended discussion in a "hard technical" class
- test the feasibility of weaving a theme throughout an engineering science class without impacting traditional coursework
- demonstrate the relevance of heat transfer and thermodynamics to important societal issues

The remainder of this paper describes the methodology of incorporation, provides details on the student assignments, and assesses the degree to which the objectives were met.

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II. Methodology

The theme was introduced into the classes in three areas: weekly homework assignments, a design project in the case of Heat Transfer, and class discussions. Homework assignments from the texts were supplemented with term definitions, essays, and problems requiring engineering calculation. In previous course offerings, I had assigned six to eight homework problems per week; with the theme courses, I replaced one or two of those with an energy conservation assignment. Students downloaded the special assignments from a *blackboard.com* website I developed for the course.

I taught the classes in the winter of 2001, which was when the California energy crisis was at its peak. The crisis provided an excellent context for our class discussions, many of which centered on editorial cartoons from the period. The first 20 or 30 minutes of one class meeting a week were devoted to discussion of conservation issues.

The senior-level heat transfer class was filled mainly with mechanical engineering students for whom this was their terminal mandatory thermal science class; Thermodynamics I was attended mostly by electrical and civil engineering students for whom it was the terminal thermal science class.

III. Description of the assignments

The assignments are listed in Table 1. They can be divided roughly into four groups: term definition, essay, calculation, and design project.

	term definition	essay	calculation	design project
Conservation is an Ethic		X		
Energy utilization and reserves			X	
Air- or argon-filled windows?[1]			X	
Practical energy conservation suggestions		X		
R-value[1]	X			
Validation of "Loft Lamp" claims[2]			X	
Energy Conservation and the Poor		X		
Two conservation-related concepts	X			
Ground-coupled heat pumps		X[2]		X[1]
The hydrogen economy		X		

[1] activity only for heat transfer class
[2] activity only for thermodynamics class

Table 1. Assignment Types.

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Conservation is an ethic. The objective of this initial assignment was to prompt student thinking on issues of energy conservation. Students read "Energy Conservation is an Ethic" by William J. Coad, Jr., where the author puts forth the rather provocative premise that energy conservation in an engineer's designs is an ethical issue[3]. He proposes that "there is a new standard of professionalism in engineering, and that is to practice our profession with an emphasis upon our responsibility to protect the long-range interests of the society we serve and, specifically, to incorporate the ethics of energy conservation and environmental preservation in everything we do." He goes on to state that

> *The naysayers in the profession may counter that the engineers are to serve the dictates of those for whom they are "employed," the business managers, the politicians, the administrators, the developers, or, ultimately, the consumers. But the engineers cannot use this haven of comfort or justification any more justifiably than the defendants of Nuremberg in 1945, whose defense was simply that they were just following orders.*

Many students agreed with the author's contention that design for energy conservation is a moral imperative (see section IV below), but some were critical of the author's tone, feeling that corporate and consumer desires should not be ignored.

Energy resources and utilization. The objectives of this assignment were to exercise the student's ability to retrieve and analyze energy data on the Energy Information Administration website and to perform some calculations to predict depletion times for a nonrenewable fuel. I also hoped to demonstrate the inordinate proportion of the world's energy resources consumed in the U.S., and impress upon the students that the world's nonrenewable resources will not last forever. I presented them with the exponential model of energy depletion and discussed its limitations. Students estimated depletion times of oil reserves for various assumptions about the consumption rate.

R-value definition. Under the assumption that most students had heard of the R-value ratings prominently displayed on packaging for residential insulation, heat transfer students were assigned a research activity to quantify the R-value. Surprisingly, the textbook made no connection between the analytical material and this common application.

Air or argon filled windows? Objectives were to expose heat transfer students to calculations with non-SI units (their text was strictly SI) and to demonstrate quantitatively why argon is used as a filler gas in thermopane windows. Students showed that the heat transfer rate through the window was decreased by 30% when argon replaced air.

Validation of "Loft Lamp™" claims. The objective was for thermodynamics students to critically evaluate advertising claims. The "Loft Lamp" is a reflective room light using compact fluorescent technology. A statement on the package claimed specific cost savings above halogen lamps and savings in pounds of coal burned. I asked students to verify the advertised figures. The dollar amount was approximately confirmed, but the claimed mass of coal saved was higher than the class calculated, probably due to a discrepancy in the figure used for heating value.

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Practical energy conservation suggestions. Students were asked to imagine that they were home-and automobile-owning working engineers and then to rank energy-conserving ideas from the Alliance to Save Energy's website[4]. This list included items like replacing furnace air filters, improving attic insulation, and using programmable thermostats. Predictably, the suggestion to "select fuel-efficient cars" was met with some negativity by these classes populated largely with aspiring automotive engineers and long-time car buffs.

Energy conservation and the poor. Objectives for this assignment included prompting students to think about environmental justice issues. Students read the "Resolution on Sustainable Energy and Low-Income and Minority Communities.[5]" The paper deals with the need for low-income and minority community participation in energy policy decision-making, such as new power plant siting. It also discusses how low-income groups disproportionately spend more of their income on energy and have more adverse health problems. Students were given a list of items to discuss in their essays, including the following question pertaining to a statement in the paper:

> *Do you agree with the statement that "utility and environmental regulators must prevent further clustering of fossil fuel and nuclear power plants in low-income and minority communities?" Why or why not?*

Twenty-seven students agreed with the statement, and eight did not. Explanations of those agreeing included "When expanding power plants careful planning should go into their location, including whether not the proposed site is in a high or low income area. Disregarding people based on their income would be unethical." Responses from those disagreeing with the statement included "low income communities need some place for people to work close to home."

Hydrogen Economy. Students were asked to describe what is meant by the "hydrogen economy," and to discuss the hurdles that must be overcome before such an economy becomes a reality, including an assessment of whether or not such an economy would become a reality in the student's lifetime. Objectives here were to encourage some independent research and prompt students to come to their own conclusions after processing information.

Two energy-related concepts. I asked students to define "sustainable development" and "green engineering." For sustainable development, I rated responses based on the following: if the writer referred to the importance of conserving resources for future use or developing designs that use fewer nonrenewable resources, I marked the definition as valid. All other definitions were marked as invalid, including no response. In some cases, I am not sure the writer knew what he or she meant, ("developing facilities (manufacturing or other) while sustaining the natural environment in the area"), but I gave responses like this the benefit of the doubt. Although vague and imprecise, statements like "developing ideas so that they are easy to implement and conserve energy" were counted as valid. Responses like "developing only what is necessary to survive" and "an invention or process that is produced and will be able to last through an amount of time" were considered invalid.

Figure 1 shows the student performance on this assignment for the definition of sustainable development. Most students gave reasonable definitions of green engineering, with a typical

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response being "engineering a product to be environmentally friendly." Unfortunately, many students simply copied definitions from web sites instead of expressing thoughts in their own words.

The definitions below were used as yardsticks.

> Sustainable development is "development that meets the needs of the present without compromising the ability of future generations to meet their own needs.[6]"
>
> "Green Engineering can be defined as environmentally conscious attitudes, values, and principles, combined with science, technology, and engineering practice, all directed toward improving local and global environmental quality.[7]"

Ground-coupled heat pumps. In Michigan, a traditional air-to-air heat pump is unfeasible for residential heating because of the low winter temperatures. A ground-to-air design, however, can be economically viable[8]. In order to introduce this promising technology to students, I assigned a one-page report to thermodynamics students and a term design project to heat transfer students. The thermodynamics students were asked to evaluate the claim that the ground-coupled heat pump technology is competitive, or ultimately less expensive, than the traditional natural-gas-fired furnace. They were asked to include both installation and operational costs in their evaluation. Disappointingly, most students did not go into quantitative comparisons (probably because I did not specifically ask them to!). Many students were convinced of the benefits of the heat pump, but some brought out the valid point that maintenance could be a problem due to lack of experienced contractors. The design project for the heat transfer students met with an enthusiastic response. The project bridged the gap between thermodynamics, fluid mechanics, and heat transfer by requiring thermodynamic cycle analysis, heat exchanger design, and pressure drop calculations (for the long underground pipes).

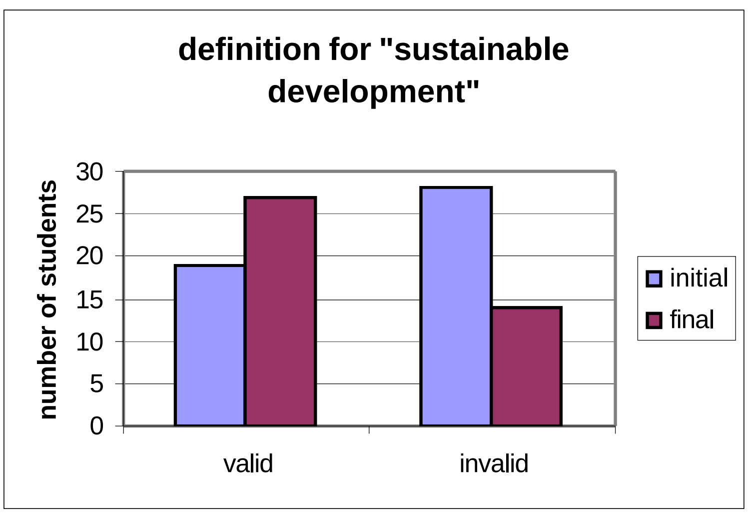

Figure 1. Results for student definitions of "sustainable development." "Initial" and "final" refer to questionnaires given at the beginning and end of the semester.

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IV. Assessment

Assessment of how well the objectives were met was accomplished through pre- and post-questionnaires, along with anecdotal evidence throughout the semester. Including both classes, 47 students took the initial questionnaire and 41 students took the final questionnaire. The extent to which each of the objectives was met is described below.

Increase student appreciation for the importance of energy conservation. For the most part, the students increased their appreciation for energy conservation issues. Most of the students believed that the material inspired them to be more energy conserving as practicing engineers and in their personal lives (see Figure 2). A typical comment was "I did not really pay attention to the conservation of energy [before taking this class] but after hearing and reading some things in the articles, I try to conserve energy at home."

Figures 3 to 5 show how student opinion changed over the semester. The same statements were presented to the students near the beginning of the term and at the end. Figure 3 shows that there was a slight increase in the number of students who found energy conservation to be a moral imperative. Similarly, Figure 4 demonstrates a slight increase in the number of students believing that energy conservation issues should outweigh customer needs. Figure 5 shows a decrease in the number of students who believed the primary purpose to conserve energy should be to save money and an increase in the number believing the primary purpose should be to ensure an adequate supply of energy resources for future generations. It is interesting to note that only one (before) or two (after) gave the avoidance of self-indulgence as a reason to conserve energy, indicating little sympathy for the suggestion that energy woes could be in any way connected to self-indulgent lifestyles.

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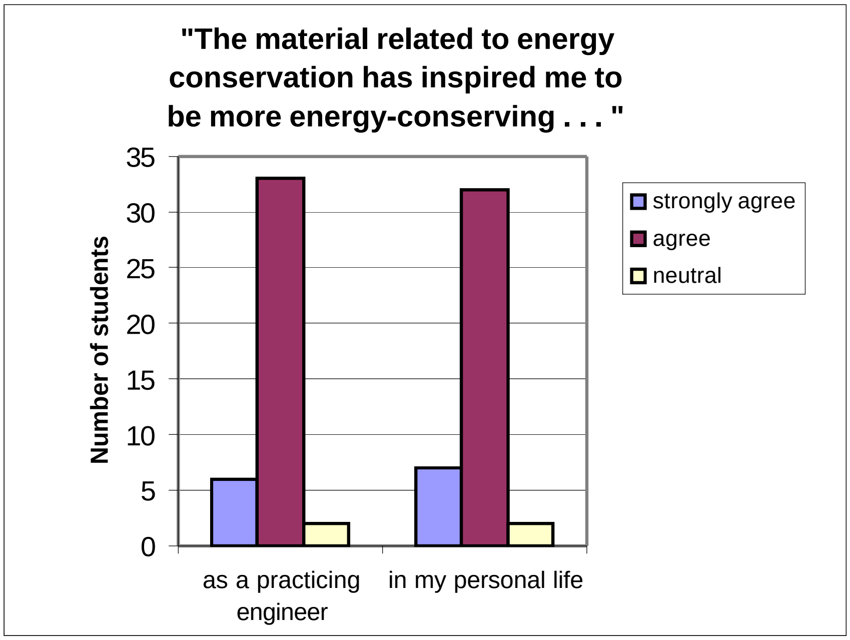

Figure 2. Student response to the statements “The material related to energy conservation has inspired me to be more energy-conserving” as practicing engineers and in their personal lives.

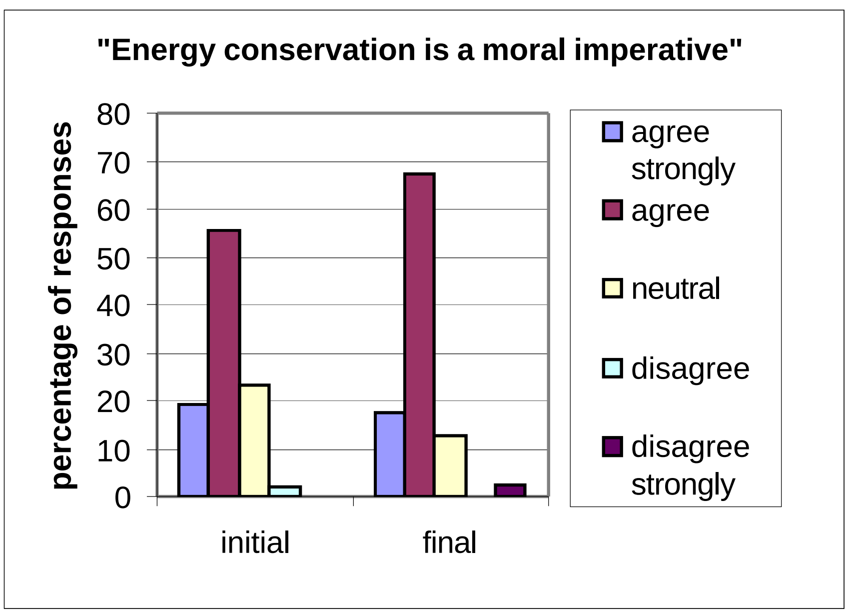

Figure 3. Before and after responses to the statement “Energy conservation is a moral imperative.”

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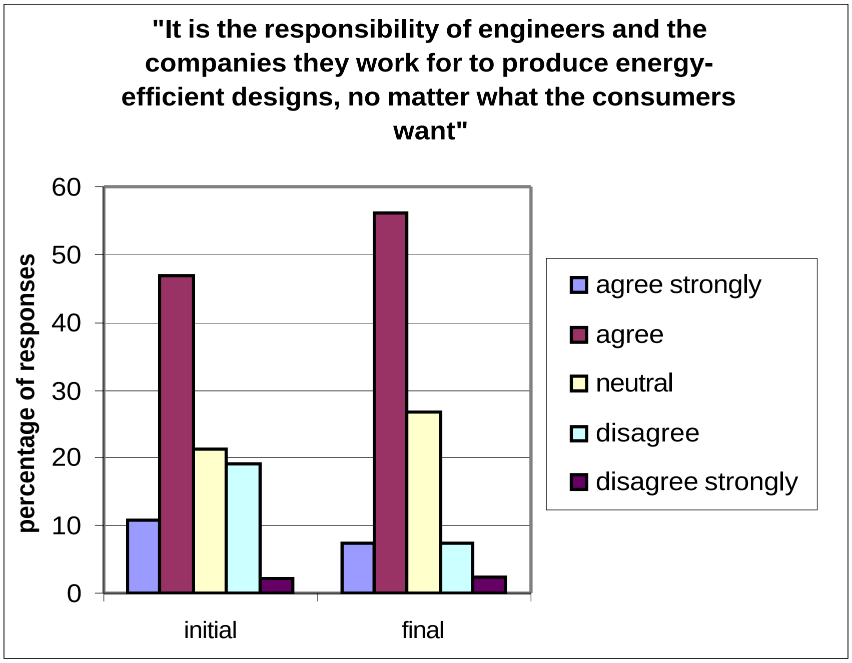

Figure 4. Before and after responses to the statement "It is the responsibility of engineers and the companies they work for to produce energy-efficient designs, no matter what the consumers want."

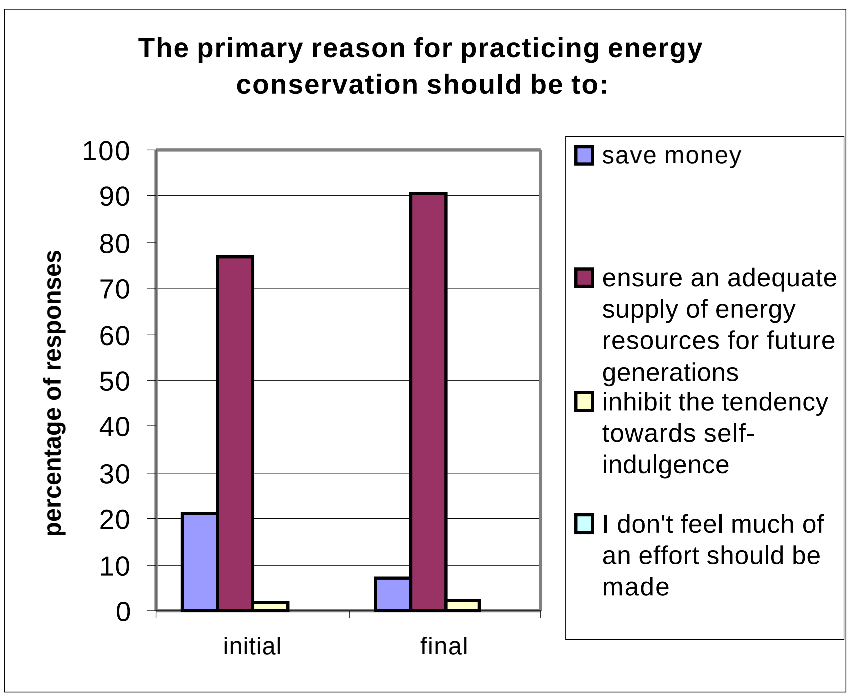

Figure 5. Before and after responses regarding what students felt to be the primary purpose for energy conservation.

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Experiment with open-ended discussion in a "hard technical" class. Most Fridays the first 20 or 30 minutes of class time were devoted to discussion of conservation issues. The discussion would often be centered on an editorial cartoon concerning a current energy-related topic such as the crisis in California. Students particularly liked this aspect of the presentation ("Awesome cartoons!" commented one student). I solicited student opinions on matters ranging from the rest of the world's perception about America's energy consumption habits (one student said, "they think negatively of Americans until there's a war") to the role of the consumer versus that of the state in conserving energy.

The open-ended discussion was slightly uncomfortable for some of the students and the instructor. Students, who are used to being largely passive observers in lecture courses, sometimes were reluctant to speak up in front of their peers. Others, however, wished that there had been more class discussion: this was perhaps a consequence of the instructor's rush to end the discussion in order to cover the engineering science material. The instructor found it difficult to avoid dominating the discussion and being tagged with the role of policy expert.

Test the feasibility of weaving a theme throughout an engineering science class without impacting traditional coursework. In order to cover the same amount of material, some material had to be cut from lectures with the instructor relying more on students to understand their reading assignments. Occasionally a student complained about the amount of homework, but if a problem was sacrificed, it was usually one from the textbook and not the conservation assignment.

Students felt nearly unanimously that future offerings of these courses should be taught with an energy conservation theme. Some felt the theme should be incorporated into more classes, including non-engineering classes. A typical comment was "I thought it was a great bonus for the course, and I've begun to notice more environmentally friendly products." Many of the weekly assignments were centered on articles dealing with policy issues; some felt the articles were biased towards more aggressive conservation practices.

Figure 6 shows that students felt the inclass discussion, design project, and essay assignments were most valuable for increasing their appreciation of energy conservation issues. Least effective was the term definition (perhaps this was a consequence of copying definitions found on the web).

Demonstrate the relevance of heat transfer and thermodynamics to important societal issues. Many of the assignments dealt with societal issues such as environmental justice and depletion of nonrenewable energy resources. I believe that most students grasped the connections between the course subjects and societal issues, particularly since the class discussions largely centered on the California energy crisis. One student commented that the portion of the class dealing with energy conservation should be expanded to "a course in itself" to be most effective in changing the way society approaches energy conservation.

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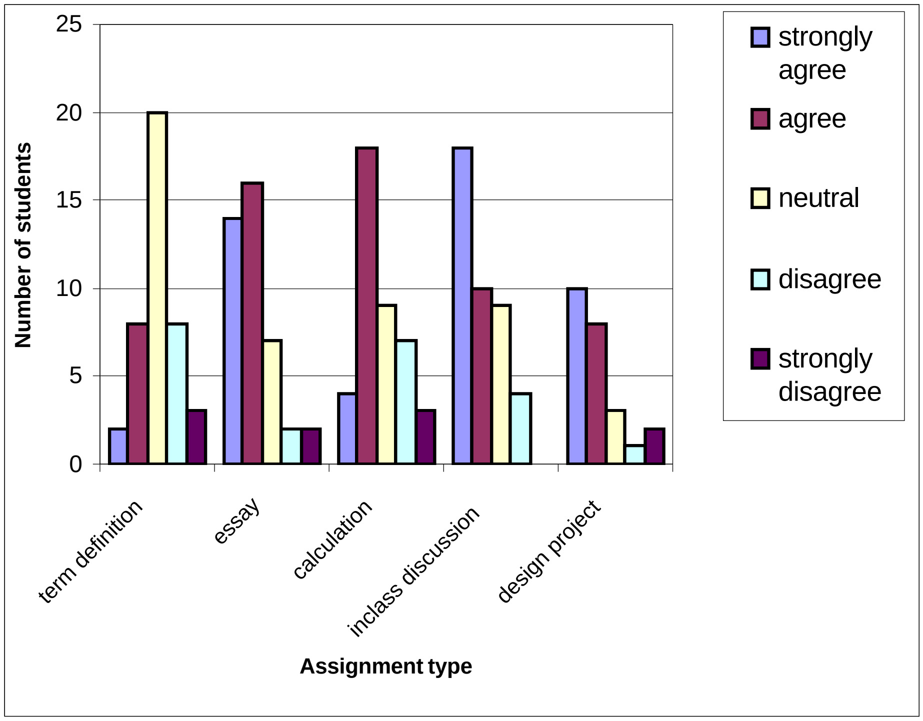

Figure 6. Student reaction to the statement "This activity increased my appreciation for energy conservation issues." The design project is only applicable for the heat transfer class.

V. Conclusion

The incorporation of an energy conservation theme was a definite asset to the classes of thermodynamics and heat transfer. As a result of taking these classes, students became more motivated to apply energy conservation principles in both their personal and professional lives. The introduction of subjective issues was a departure from the "safe" lecture format, but added memorable class discussions to the classroom experience. Although the initial introduction of material added to the instructor's preparation time, student workload was negligibly impacted, and subsequent offerings should require less preparation.

Bibliography

1. Young, V.L., and Stuart, B.J. The Theme Course: Connecting the Plant Trip to the Text Book. *Journal of Engineering Education*, vol. 89, no. 4, pp. 475 – 479 (October 2000).
2. Manteufel, Randall D. A Spiral Approach for Mechanical Engineering Thermodynamics. 1999 ASME Curriculum Innovation Award – Honorable Mention at *www.asme.org/educate*.
3. Coad, William J. Energy Conservation is an Ethic. *ASHRAE Journal*, pp. 16-21 (July 2000).
4. URL *www.ase.org.*
5. Renewable Energy Policy Project. Resolution on Sustainable Energy and Low-Income and Minority Communities (Fall 2000). URL *www.repp.org.*
6. The World Commission on Environment and Development (Brundtland Commission). *Our Common Future.* (1987).
7. URL *www.eng.vt.edu/eng/green.*

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8. Department of Energy, Office of Geothermal Technologies. Geothermal Heat Pumps Make Sense for Homeowners (September 1998). URL *www.eren.doe.gov/geothermal/pdf/26161b.pdf.*

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