A Learning Community Approach To Development Of A Sustainable Energy Course

Cortney V. Martin[1], Michael W. Ellis[2], David D. Dillard[3]

Abstract – The sustainable energy field is rapidly evolving and garners much attention in the media and thus among students, who recognize that renewable energy issues offer significant engineering challenges and opportunities for their careers. In response to student needs to better understand this field, we developed a special topics senior-level course entitled "Sustainable Energy Solutions for a Global Society" using a learning community approach that directly involved students in knowledge- and course-building. This was important due to the breadth and rapidly changing nature of this field and because we wanted to encourage students to develop skills for surveying and critically evaluating emerging technology. To date, the course has been offered and fully enrolled over three consecutive semesters. The course has evolved, but the learning community approach has been maintained and students continue to enjoy an active role in developing materials used in the course. This paper addresses the course objectives and topics, observations on the course development process, and strategies used in fostering student ownership and participation.

Keywords: Sustainability, energy, learning community, course design.

About the Course

There is some concern that while sustainability is gaining traction in mainstream society, its incorporation into the curriculum is lagging [1]. The Sustainable Energy Solutions (SES) course was developed by faculty representing three engineering departments in response to the need for students embarking on engineering careers to develop an understanding of energy resources, energy conversion processes, and the broader impact of energy on society and the environment.

The three-credit course, offered jointly through the Department of Mechanical Engineering and Engineering Science and Mechanics, has as its objective to:

> Address energy metrics, global and US energy supply and demand, transitional energy sources (natural gas, petroleum, coal, nuclear), sustainable/renewable sources (solar, geothermal, hydro, tidal, wind, biofuels), and methods for increasing efficiencies (energy storage, batteries, green building, conservation). Explore transportation, electricity, lighting and heating needs of industry, agriculture, community, and citizens. Production, transmission, storage, and disposal issues are considered in the context of global political, economic, and environmental impacts.

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Offered as a 4000 level class (primarily seniors and a few juniors), course prerequisites include chemistry, physics, and a junior technical writing course. As an alternative to the technical writing course, we accepted senior standing in a department that has a formal writing plan embedded in the other requirements of their curriculum. The SES course serves as a technical elective for the College of Engineering and counts toward the Green Engineering minor.

Learning Objectives

The overarching course objectives were designed to support the ABET Outcome Objectives [2] that contribute to essential technical and professional skill sets for graduate engineers. Table 1 gives the course objectives, shows how each relates to the ABET Objectives given in Table 2, and indicates the level of emphasis in the course.

Table 1. Course learning objectives as related to ABET Program Outcome Objectives 2008-09

Learning Objectives/Elements	**Program Outcomes**										
	a	b	c	d	e	f	g	h	i	j	k
Define and explain key energy and energy use metrics and use to evaluate current and proposed energy systems.	1		2		2						
Explain fundamental concepts of thermodynamics needed to understand and compare energy systems.	1		2		2						2
Demonstrate a broad working knowledge of the scientific bases and engineering tradeoffs of transitional and sustainable energy solutions.	1		2		2			1			
Identify and discuss key global political, economic, cultural, and environmental implications of energy options for several geographic regions.	1							1		2	
Evaluate and critique proposed energy solutions from technical and societal impact standpoints.	1			2		3	2	1		2	

1. Major emphasis of course.
2. Discussed in the course and covered in homework or quiz.
3. Mentioned in the course but not included in homework or quiz.

Table 2. ABET Objectives for Program Outcomes 2008-9

a) an ability to apply knowledge of mathematics, science, and engineering
b) an ability to design and conduct experiments, as well as to analyze and interpret data
c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
d) an ability to function on multidisciplinary teams
e) an ability to identify, formulate, and solve engineering problems
f) an understanding of professional and ethical responsibility
g) an ability to communicate effectively
h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
i) a recognition of the need for, and an ability to engage in life-long learning
j) a knowledge of contemporary issues
k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Course Topics

Faculty worked collaboratively to develop the initial set of topics (see Table 3). The selected textbook was *Energy Systems Engineering: Evaluation and Implementation* by Francis M. Vanek and Louis D. Albright [3]. We wanted the course to be open to students from all engineering (or relevant technical) disciplines several of which do not require a thermodynamics class. Thus, background material addressing energy metrics and the basics of energy transformation was introduced early in the course. In addition, while the focus was renewable/sustainable energy, we quickly realized that students needed a more comprehensive understanding of the larger energy solution space including more traditional or "transitional" energy options. Following a discussion of transitional energy options, we covered each of the major renewable energy technologies. We then discussed approaches for energy storage and conservation. Finally, we concluded the course by asking students to apply what they had learned to specific real-world environments.

Table 3. Categories and topics in initial course offering

Category	Topic	Responsibility
Energy Basics	• Energy and environmental metrics • Transforming energy	Faculty
Geopolitics and Economics of Energy	• Global energy supply and demand • US energy supply and demand • Energy economics and policy	Faculty
Transitional Energy Technologies	• Petroleum • Natural Gas • Coal • Nuclear Power	Students and Faculty
Renewable Energy Sources	• Solar • Hydro and Tidal • Wind • Geothermal • Biofuels	Students and Faculty
Efficient Energy Use	• Energy Storage and conversion • Advanced power plants • Green buildings • Conservation • Transportation technologies	Students and Faculty
Connections	• Choosing among options • Consumer, campus, and commercial sustainability	Students and Faculty

BUILDING THE CLASSROOM LEARNING COMMUNITY

Learning community frameworks are being increasingly utilized in classrooms because they are recognized as providing pathways to greater student learning and development – personal, interpersonal, and epistemological [4,5]. There are many contexts for learning communities in both formal and informal educational settings, but the common theme is that the students are actively and collaboratively vested in their own learning, which results in greater student engagement. Learning communities are well-suited to contribute to the training and development of engineers in areas such as teamwork and communication skills, but also in collaborative design, problem solving, ethics, and an understanding of the larger context for their work.

The initial course was open to students both within and outside of the College of Engineering to provide the richest set of input. Among the 20 students, the following departments were represented: Biological Systems Engineering

(1); Chemical Engineering (6); Civil Engineering (3); Computer Engineering (2); Electrical Engineering (2); Engineering Science and Mechanics (2); Mechanical Engineering (1), Biology (1); Environmental Policy and Planning (1); and Humanities, Science, and the Environment (1). There were three female students, and one female faculty.

Pre-Course Student Input

When the goal is to actively involve students in constructing and delivering content in the classroom, proper framing is important to achieve buy-in. We disclosed our inclusive approach, which led to very positive student reactions and engagement. Prior to developing the course syllabus for our initial offering, we emailed a survey to the 20 enrolled students to let them know they would play a role in some of the specifics of the course design but also in contributing content. This survey set the tone for the learning community approach and made us aware of the breadth of student experiences and knowledge they would be bringing to the course.

The survey questions included:

- What interested you in this course?
- How do you expect to use this information in your future in terms of graduate school, career, or personal use?
- What topic areas are you most interested in? Least interested in?
- Describe any experiences or background you have in sustainable energy areas. This might include work experience, personal projects, mission trips, or books you have read.
- Projects, activities, and assignments help us to get the most out of material...and out of ourselves. Digging in gives us pause, show holes in our knowledge, and helps us to understand and resolve issues. How would you like to engage with the material? (e.g. lead a class lecture, do a service project, writing assignments, exams, etc.) Think about what has worked well for you in other classes. You might also mention things that have NOT worked well!
- We may have the opportunity to work with the YMCA's Greenhouse project that is underway on North Main Street. They are looking for recommendations to incorporate sustainable energy on the 15 acre site that includes a spring-fed pond and creek. What are your thoughts regarding this?
- Do you have any other ideas/suggestions/questions about the course?

The responses were wide-ranging, but generally students acknowledged the importance of acquiring a greater understanding of the energy picture. "*I want to learn more about sustainable energy possibilities because it is the future of engineering. I think social and environmental sustainability is an extremely important topic. Meeting energy needs is a large and difficult challenge within sustainability, and I am interested in learning all I can to help develop solutions.*" Others were interested in the small class size and collaborative approach, "*I was also drawn by the fact that the class size would be kept small which would allow for the class to really come together and it would not be an impersonal lecture setting*." Some even acknowledged the benefits of being involved directly in teaching peers, "*I think leading a class lecture sounds interesting. The best way to learn is to teach others*."

Fostering Community

To foster community among the pilot group, we asked students (and faculty) to provide an introductory slide at the first class. They were encouraged to include photos, images, and bullet points to describe themselves professionally as well as personally if desired. The purpose was to get to know one another to begin building the learning community more quickly. We incorporated tent cards with names, and sat with seats arranged conference room style to facilitate discussion and interactions.

CO-CREATING CONTENT

Incorporating the pre-course student input, the faculty created a common foundation by leading lectures and discussions on energy basics and the geopolitics and economics of energy. We brought in guest speakers from departments across campus as well as industry to emphasize the interdisciplinary and global nature of energy issues. When possible, we provided hands-on opportunities such as the chance to examine and drive an electric car as (see Figure 1).

Figure 1. Students with an electric car

Early in the semester, we showed the video “Crude Impact” to introduce students to the theory of peak oil and environmental issues.

After the initial period of faculty-led foundation classes, students took a more active role. They worked in groups of five to collect resources, post online content, and prepare and deliver a presentation on one of four transitional energy areas (petroleum, natural gas, coal, nuclear). The class was then divided into pairs to conduct the same information gathering and presentation process for each of ten areas related to sustainable energy (advanced power plants, biofuels, conservation, energy storage, geothermal, green buildings, hydro and tidal, solar, transportation, and wind). To organize the groups, we asked students to choose their top three topic areas for each category (transitional energy and sustainable energy), and we did our best to match them to their interest areas.

To provide context and relevance, we defined a target audience as ”a multidisciplinary group of researchers who have gathered to broaden their understanding of transitional energy areas”. Students were asked to focus on the current status and prospects for their assigned areas, the contribution of their assigned areas to the short term and long term energy future of the US and the world, and the limitations and opportunities associated with their assigned area. The goal of the assignment was to help students explore the costs, impacts, innovations, and uses associated with each energy area, as well as the underlying physics so that they can better understand the energy choices available and make more informed decisions.

The online course management system used by Virginia Tech, *Scholar*, was used to organize and present information. Scholar contains a Wiki feature to which groups posted the following information:

- Overview of the technology and example of the system from “well to wheels”
- Economic costs per unit of energy
- Government subsidies, if any (US and other countries)
- Environmental costs and impacts
- Emerging technologies (e.g. to improve efficiencies or reduce impact)
- Top research areas
- Two or three "required" readings for the rest of the class. One must include a case study implementation of the technology in a region outside of the US
- Annotated bibliography of the "top ten" resources in this area. This should include a mix of web sites, books, book chapters, journal articles, and videos.

Student Assessment and Engagement

Student assessment included class participation, exercises, quizzes, the transitional and sustainable energy presentations, a semester project, and a final course reflection. The transitional and sustainable energy presentations and materials were evaluated by both the faculty and assigned peer evaluators, further supporting the learning community in which students were responsible to one another.

Quizzes were take-home with both quantitative and qualitative-type questions that were framed as an opportunity for students to analyze, synthesize, and present information and evidence from the speakers, text, and videos, as well as outside resources. These were evaluated based on depth of analysis and demonstration of linkages among concepts. Seven questions were given and students selected four to answer.

The course project emphasized relevance in a real-world context. In the first semester we asked students to investigate how (or if) their sustainable energy area (assigned presentation group) should be implemented in a new YMCA community greenhouse project. We toured the 15 acre facility and learned about the needs for building, electricity, heating, cooling, and irrigation. At the end of the semester, students presented their solutions to the leaders of the greenhouse project.

We encouraged students to bring in information from related speakers, events, and media. One extra credit point was awarded for those who wrote up and posted information about an appropriate outside event on the Wiki.

STUDENT FEEDBACK

At the end of the semester, we invited student feedback via an anonymous online survey to assess what went well, but more importantly, to uncover areas for improvement. Students were asked to evaluate the learning community approach, the value of the student led presentations and quizzes, and the contribution of the course to their professional development. Students identified course weaknesses and suggested potential solutions.

Learning Community

Students overwhelmingly appreciated the highly interactive nature of the class: "*The best part was the participatory learning. It seems easier to discuss things when students are presenting than when professors are lecturing*." They benefited from the collegiality: "*It gave me a chance to get to know many more people than I usually would taking a class*." Students felt a heightened sense of responsibility because they were accountable to their peers and not just to themselves and the faculty:

> *"My largest gain in the course was an approach to learning and a sense of responsibility to my classmates. Emphasis on student projects in the quizzes caused me to feel accountable for the information I presented. In the real world engineers' remarks are taken as fact and real money and safety are at stake. I found this approach sobering."*

Presentations

Students felt that the breadth of topics covered in the presentations was good: "*I think it captured pretty much all of the information you would need to know to make decisions on choosing an energy choice*." However, the quality of the presentations varied, and classmates were the harshest critics! "*The downside is that some of the things that made it into the presentation were questionable - the solar microwave power satellite is one example that comes to mind that has been repeatedly debunked.*" "*Some groups do fall short so you don't get a good well rounded view of the choices, that is just inherent to the way this is done, not really a big deal*."

Quizzes

Take-home quizzes with multipart quantitative and qualitative questions are uncommon among traditional engineering courses. For many students, this was their first and only exposure to this type of work. They responded very favorably, recognizing that much of their learning took place outside of the classroom as they worked through complex scenarios and drew from multiple sources.

> *"The exams were great. I got to apply what I learned in class and state my own opinion. Most of the time in chemical engineering, we're focussed on the "right" answer. There's only one, and not getting it costs points. There was no right or wrong answer with these assignments. Creativity, problem solving, and research were the only way to get a good grade. It was challenging, but rewarding. I was extremely satisfied when I received a 98 on quiz 2. I spent a lot of time on it, and enjoyed the work a lot. It was honestly one of my most rewarding grades. Keep them the way they are."*

"The exams were interesting. I did not think I was gaining much from the course until I completed the exams. After that I realized that the class was doing exactly what I hoped it would do. This became more evident when I talk to people outside the class and they are amazed at the technology that is available and that is being developed."

Professional Development

Students often found that this course added focus to a chosen career pathway or provided needed direction or motivation.

"I have now learned that I want to focus my chemical engineering career in the field of sustainable energy solutions. The world has a problem, and I want to be on the front line of the solution. I always thought I wanted to do this, but this class proved to me how much fun and rewarding this field can be. It's completely innovative and challenging, but at the same time necessary. This class has helped me a lot."

Recommendations and Areas for Improvement

While the collaborative learning-community approach was generally appreciated, students made a number of suggestions for improvements.

Table 4. Course weaknesses and proposed remediations.

Weakness	Proposed remediation
Student presentation quality varied and sometimes important concepts were neglected	Include more expert/instructor-led lectures; perhaps alternate these with student presentations
Not enough quantitative work such as engineering analysis and calculations	Add in out-of-class quantitative exercises and homework.
Project context (Y Solar Greenhouse) did not apply equally well to all sustainable energy topic areas	Broaden the scope of project topics. In the second offering it was anything in the campus sustainability plan; in the third it was fully opened up.
Attendance dropped off during the semester. The most common reason given was that this was an elective and therefore a lower priority. Another reason was that not all student presentations were high quality	Create a system of accountability for attendance. In the third offering, DyKnow was used and students were required to submit questions to student presenters at the start of class for incorporation into the lecture.
Difficult to balance presentation materials with class discussion	Devote some class periods to debates
Quizzes were good but time consuming	Spread questions throughout the semester, such as one or two per week

Course Redesign

In response to student feedback and faculty observations, a number of modifications were tried in two subsequent offerings of the course.

Balance of Faculty/Student Led Class Sessions

In the second offering of the course, we shifted the balance from a predominantly student-led course (20 student-led and 10 faculty-led classes in the initial offering) to a predominantly faculty-led course (7 student-led and 23 faculty led classes). In the third offering, we settled on an intermediate level of student leadership (12 student-led and 18 faculty-led classes). . In both the second and third offerings, faculty assumed responsibility for Energy Basics, Geopolitics and Economics of Energy, and Transitional Energy Technologies. Then we dedicated two class periods to each sustainable energy topic with an overview of the resource provided by the faculty on the first day, and a set of 2-3 in-depth case studies presented by a student group during the second class period.

Peer Review

Following the initial offering of the course, we moved away from a peer review system for student-led presentations to a faculty review system. We found that students had great difficulty reviewing one another objectively on paper. From the end-of-semester survey it was clear that students could easily distinguish the good from the bad, but perhaps that became more apparent to them in hindsight. This is an area to revisit after further research.

Current Events

In the initial offering of the course, students often brought current events to class which sparked considerable debate and inquiry. In subsequent offerings, we formalized this practice by asking pairs of students to be responsible for finding and posting a current event related to the week's topic then presenting it during the first 5-10 minutes of class. They were asked to post a synopsis, provide a link to the primary information source (organization, news outlet, scholarly journal), identify three to five links to related information, and suggest three questions of critical analysis for the class to consider.

Outside Events

As with many campuses, Virginia Tech offers a rich set of energy-related speakers, events, panels, documentaries, and excursions. In the second and third offerings of the course, we asked each student to attend two outside events and write and submit a one-page synopsis for each. We considered having students post these for others to read but did not find a workable solution that would eliminate temptations to copy and submit write-ups for events that were not attended.

Debate

In the second offering of the course, we added a climate change debate in which student groups were assigned a number of related readings to study and present to the class. This was followed by a class debate about the evidence and how to resolve issues of conflicting data. In the third offering of the course, four mini-debates were held, spanning 2 days, with topics on climate change and the urgency to address it, nuclear power, and the need to urgently pursue carbon sequestration.

Quantitative Analysis

In the second and third offerings of the course, we increased the focus on quantitative analysis covering topics such as: energy, power, work, heat, efficiency, economic lifecycle analysis, causal loop diagrams, solar radiation, and wind power calculations. These topics were addressed in class, through homework assignments, and on exams.

Project

During the second course offering, Virginia Tech was in the process of finalizing a significant report on the Campus Climate Action Commitment and Sustainability Plan. A representative from that committee presented the work to the students and we charged student groups with creating a semester project that that directly supported that effort. Project topics included whether a "no freshman car rule" would indeed decrease energy use, an energy analysis of demand control ventilation in one of our largest classrooms, and an investigation into biomass options for the campus power plant. This seemed to increase personal relevance and quality of the projects. In the third offering, the project was further expanded to include any approved topic relevant to sustainable energy.

RECOMMENDATIONS FOR COURSE DEVELOPMENT AS A LEARNING COMMUNITY

While we adopted the learning community approach initially to help capture information on a wide range of emerging technologies, we quickly recognized that structuring the course in a way that encourages deeper student investment, engagement, and accountability benefits students and faculty. As one student put it, "*The passion in the* *class from the professors and students was contagious. I feel that is the single best tool this class has to inspire students*."

We strive to maintain those beneficial attributes of a learning community while ensuring that students get the consistently high quality course experience that will support them in their professional endeavors. Toward that end, we make the following recommendations for this type of course:

- Solicit input prior to the semester regarding content and incorporate areas of interest into the syllabus
- Build the learning community by forging relationships among members through specific actions (e.g. arrange seating to encourage discussion, provide team assignments, etc.)
- Work toward an appropriate balance of faculty- and student-led classes
- Include guest speakers and local field trips
- Create connections to current events, campus events, and professional development
- Develop assignments that encourage analysis, synthesis, and outside research
- Feature a relevant project that has meaning and can be used as a portfolio piece for students
- Have a good system of accountability for class participation.

A learning community approach is particularly valuable in a course based on rapidly changing and evolving information. It allows the course to stay fresh and enables students and faculty to work collaboratively to gain an understanding of the current and future directions of related knowledge and research.

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