AC 2012-4093: ADDRESSING THE BROADER IMPACTS OF ENGINEERING THROUGH A GENERAL EDUCATION COURSE ON GLOBAL ENERGY ISSUES

Dr. Lawrence Holloway, University of Kentucky

Lawrence Holloway is TVA Professor and Chair, Department of Electrical and Computer Engineering, and Director, Power and Energy Institute of Kentucky (PEIK), University of Kentucky.

Addressing the Broader Impacts of Engineering through a General Education Course on Global Energy Issues

Abstract:

In Fall 2010, a course on *Global Energy Issues* was developed as part of a multidisciplinary undergraduate certificate in power and energy. The course was designed to address the policy, economic, and societal issues of energy, in order to complement the more technical courses required as part of the undergraduate certificate. In order to minimize any additional credit hours required of students pursuing the certificate, the course was also designed to fit within the University's new General Education requirements as a "Global Dynamics" course. The course is also well suited to cover the broader "impacts" of engineering as required by ABET. The paper also overviews class structure and teaching method to promote active student inquiry into the material.

I. Introduction

In Fall 2010, the University of Kentucky received a grant from the US Department of Energy to create the Power and Energy Institute of Kentucky (PEIK), a multidisciplinary education program to increase the number of students in power and energy. An important part of the education program is an undergraduate certificate in power and energy. Within that certificate program was a need for a course to cover societal, economic, and policy issues of energy, as a complement to the more technical aspects of power and energy covered in other classes in the program. This "Energy Issues" course would be a required course for the certificate.

A significant challenge to offering new kinds of courses in many undergraduate engineering programs is the relatively high number of required courses for graduation, and the resulting lack of room for open electives outside of the main program of study. In order to allow students to take a course examining broader aspects of energy without adding more credit hours to the required courses, it was decided to tailor the possible course to fit within the university's General Education program, i.e. to satisfy as a course within the general requirements of all students within the institution. Opportunity knocked when the university revamped its General Education curriculum to include a requirement that all students take a course in global dynamics. It was decided to retarget the proposed certificate course to focus on Global Energy Issues as a way to cover the expected material on societal, economic, and policy issues of energy, while allowing the students to take the course to satisfy one of their General Education requirements. This redirection of the course to have a global emphasis was not a stretch, given that these days energy issues abound in every country. The only challenge was to collect and target international examples that would be challenging and stimulating throughout the course.

The course is unusual for an engineering course. Although the course does overview technologies associated with energy, it devotes considerable time to addressing the broader impacts (both positive and negative) of society's energy use. This is often done in the context of current events (such as recent discoveries of new offshore oil reserves in South America, the Deepwater Horizon oil spill, the Fukushima nuclear incident, the Keystone XL pipeline debate, international agreements on CO_2, etc.). As such, the class becomes a vehicle for addressing several ABET engineering accreditation student outcomes[1] . In particular, outcomes (h) and (j):

> *"(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context"*
>
> *"(j) a knowledge of contemporary issues"*

In the past the engineering curriculum addressed the broader impact of engineering solutions as one aspect in many courses, the advantage here was that Global Energy Issues gives the students a single assessable course where they can focus on the impacts, positive and negative, of engineered systems. The course also lets them understand that the impacts also operate in reverse -- that is, broad societal, political, environmental, and economic concerns often impact the forms and functions of a society's technology.

As a course satisfying a university General Education requirement, the course is not limited to engineering students. In the past three semesters of offerings, most of the students are engineering (electrical, mechanical, civil, computer, chemical, and mining engineering), but the class has included occasional students from agriculture, biology, political science, and undecided majors. Although the course was intended to be accessible to freshman and has no prerequisites, almost all students have been sophomore level and above.

No single textbook was found that sufficiently addressed the various goals of the course. For the coverage of linkages between energy and economics and society, a text book by V. Smil has been required, but the text does seem dated given the rapidly developing energy field [2]. To provide sufficient breadth of energy topics and impacts, and to provide sufficient global coverage, the course increasingly relies on articles in news and general science interest magazine websites, as well as survey articles in technical magazines and reports by government agencies and non-governmental organizations. These readings are typically available freely on the internet, or accessible through internet sites from computers on campus via campus libraries' subscriptions. The course has reading assignments for almost every class period. Many classes also include short informational videos from news sources. These videos are used as a lead in to discussions, as well as to provide a variety of teaching materials to reach students with different learning styles.

II. Course Design Principles

In order for the course to satisfy the University's requirements as a Global Dynamics course within the General Education curriculum, the following objectives were established for the course:

1. *At least 50% of the course will focus on the global aspects of energy.*
2. *Students will demonstrate an understanding of the change of energy sources and uses over time, and will understand energy in a comparative and cross-national manner.*
3. *Students will understand how energy issues affect different communities, nations, and regions, including the impact of energy on the economic, cultural, social, and political aspects of these communities, nations, and regions.*
4. *Students will demonstrate an understanding of the civic complexities and responsibilities of energy choices and policies, including both the commonalities and the differences globally.*
5. *Students will demonstrate an awareness of the elements of at least one non-US culture or society with respect to energy. This is done through the class project.*
6. *Students will demonstrate a grasp of the global inequalities and diversities that exist with respect to energy across the world.*

These were the objectives specifically for the Global Dynamics General Education requirement. In addition to these were broader objectives regarding understanding: the basics of energy; the mix of sources including pros and cons of each; the basics of electric power transmission and use; and the environmental, economic, political, and social aspects of energy,

The course is divided into five major blocks.

Energy Basics: This section of the course covers definitions of power and energy and efficiency, as well as measurement units, energy transformations, and basic thermodynamic principles of energy. This section is more technical than the rest of the semester and has little "international" content to it, but it does lay a foundation of terms and concepts necessary for students to be able to understand other portions of the course.

Energy Sources: The course next briefly examines the history of energy use. Global energy substitutions over history are illustrated through Fischer-Pry/Marchetti diagrams.[2] Students are shown how economic and political events influenced changes in the energy mix of individual countries over time. Sankey diagrams are introduced, and students learn how to analyze these for different countries to understand the current energy mix for countries, including how geographical, industrial, political, social, and other factors influence this mix. (Students do these analyses in more detail for a country of their choosing as part of their final project.)

Individual energy sources are then covered, including coal, oil, natural gas, geothermal, solar, wind, biofuels, hydroelectric, and nuclear. For each of these, students learn about which countries are leaders -- leaders in use, in production, and in export (and in reserves, in the case of fossil fuels). For each of the energy sources covered, there is a mix of technical and societal aspects. On the technical side, for example, they learn the advantages of different types of solar power generation, as well as the power availability issues and its potential based on geography. For example, for coal, there is a discussion of how variations in coal grade, ease of mining, and geographic issues affect coal pricing, as well as environmental aspects to mining and use of coal. When discussing oil, price volatility over time and international issues are covered, and when covering gas, fracking and the environmental debate is discussed. When later covering hydroelectric power, students read articles on environmental aspects of China's Three Gorges dam, as well as economic and environmental aspects of the proposed Inambari dam in the Amazon.[3,4] Even when considering wind and solar, students consider not just the technical aspects and the positive aspects of renewable energy, but also issues with variability and concerns people have raised regarding their environmental and aesthetic impact (NIMBY syndrome).

Electricity transmission, distribution, and use. Students learn very basic issues about AC and DC power transmission, pricing issues of electricity, challenges with the current grid as society moves towards renewables, and issues with power demand fluctuation/peaking. Smart Grid efforts are covered, including goals of reducing peak energy use, giving real-time pricing for consumers, and improving grid control and reliability, as well as concerns about cybersecurity and consumer privacy.

Broader societal and environmental aspects, including national security. Throughout the semester, societal aspects of individual energy sources (coal, oil, nuclear, etc.) are considered when discussing each source. By mid semester, broader themes that apply across energy in general become the focus. Energy influences almost all aspects of our modern society, from our food availability, to the location and size of modern cities, to the goods and services we enjoy. What is sometimes surprising to students is how energy can affect communities in the developing world. Students are assigned to read excerpts from a World Bank report analyzing the impacts of new electrification on rural communities in the developing world, and they learn the linkages between electrification of communities and education, economic opportunity, health, mortality, and even fertility rates [5]. Students also learn factors which help them to explain differences in energy intensities (total energy use per GDP) of different countries. This includes coverage of cultural differences in views on energy use, including some countries' efforts (such as Japan's Super Cool Biz campaign [6].) to change the culture of energy use.

Societal aspects include broader policy and regulatory issues. Students learn basic types of environmental regulation policies, arguments for and against utility regulation/deregulation, and policies used to change energy use or energy mix. National security aspects of energy are examined, including not only vulnerabilities of importing countries, but also the dependencies and problems (such as Dutch disease) for countries which are rich in natural resources. Students also learn about military aspects of energy, including efforts to reduce military dependence on energy.

Country-specific analyses of energy. At the end of the semester, students are assigned to do an energy study of some country of their choice other than the USA. The students will submit a report, and will also make a brief presentation. In the energy study, each student provides information about the country useful in understanding its energy profile, including its population, industries, land characteristics, population characteristics, natural resources, GDP, climate, etc. The student will then provide information on the energy characteristics of the country, including the makeup of the total primary energy supply for the country including energy imports and exports and major uses of energy for the country. The student will then provide an analysis, discussing changes in the energy characteristics over time, with an explanation of any political, social, economic events that influenced these changes. A comparison analysis is also done, comparing and contrasting the energy profile of the selected country with a second country, including possible hypotheses as to the reasons for commonalities and differences. The students must then conclude with any recommendations they may have for future energy policy for the country. These may be policies or roadmaps that already exist for the country, but the student must discuss and defend them. This last requirement is useful because it puts students in the role of policy maker rather than engineer.

The country-specific analyses turn out to be very illuminating for the student doing them and the students in the audience as well. The project forces the student to bring together concepts learned over the semester and then use them for analysis of an actual country's situation. As students hear presentations regarding the different countries, they learn from each other about the wide variation there is the world regarding energy use, and the many, sometimes surprising factors that contribute to these differences.

The students must limit their presentations to 5 to 7 minutes. To improve the presentation skills and ensure that they can present within the time period, students are required to practice their presentations at the eStudio, a program within the college of engineering for teaching students multimedia (oral, written, and other) presentation skills.

III. Class Structure

The “Global Energy Issues” course is taught in a typical 3-day per week one-hour course schedule. The format of the course, however, is not typical for an engineering course, for several reasons.

1. **Reading intensive:** Students have significant reading assignments for almost every class period. These readings are typically recent newpaper or magazine articles (such as from New York Times, Reuters, Popular Science, National Geographic, etc.) or technical articles or reports (such as from IEEE Spectrum, Scientific American, USDOE Energy Information Agency, and others). To ensure that students complete the readings prior to

class, the students are given reading comprehension homework questions targeting key concepts, short in-class quizzes, or assignments to write a 1 to 2 page statement as a summary and commentary on the reading. Some of these reading assignments are "open", where the student must find an article on an assigned topic, and be prepared to discuss in the class.

The reading assignments have three main purposes. First, they are necessary to expand the breadth of knowledge of these students beyond the material covered in the class period. Second, the breadth of sources and topics is intended to pique students' interest in the area, familiarize them with the wealth of possible information sources, and hopefully inspire them to read beyond the class requirements. (This is intended to contribute towards ABET EAC Student Outcomes Criteria "*(i) a recognition of the need for, and an ability to engage in life-long learning*" [1]) The third reason for the readings is to expose the students to a diversity of viewpoints on energy topics, for example, by giving the students articles emphasizing opposing aspects of an issue. The intent is for the student to understand that many issues are complex, and the students' role as global citizens (and future engineers) is to weigh the pros and cons to make good decisions.

2. **Discussion intensive:** Approximately once per week, a portion of a class period is devoted to targeted discussions. The reading assignment for that day will either be an article of the student's choice from a set of instructor chosen articles, or an article found by the student on a particular assigned topic. Students are told to prepare to give a brief oral summary and commentary to the rest of class. To ensure that all students be prepared for participation in discussions, the instructor uses a very simple but effective technique – a deck of index cards, each card having the name of one student. At the beginning of the class period, the instructor assigns a student to shuffle and cut the deck. Student names are then drawn, and those whose names are drawn must then briefly present their reading to the rest of the class. In this way, all students have to prepare to lead a discussion in the class, although only a few will be selected each time.

   Such brief and informal class presentations serve several purposes. First, they provide students experience in giving short oral presentations. Knowing that he or she may have to present an article forces the student to think about the article and decide what messages are most important to convey. Second, the class presentations create a more interactive environment. Even during subsequent lecture periods, students know that their input is welcome and expected, and are thus more open to engaging in discussions.

   A third purpose of the informal class presentations is to have the students learn from each other about several aspects surrounding a topic. For example, in discussing wind energy, a set of recommend articles may include articles focused on wind issues in different countries (such as Spain, Scotland/UK, Denmark, China, and areas of the US). Each article may have a different emphasis, such as on replacing the use of fossil fuels, economic and trade issues, transmission and supply/demand challenges, and environmental or aesthetic concerns. From the randomly picked student presentations, the other students in the class get a feel for a wide array of issues around the selected topic. After a few of the students give their statements based on the drawing of the cards, discussion is opened up to other students, who will typically bring out additional points from their own articles.

Such a discussion session poses several challenges for an instructor. The instructor has several key learning points intended for such a session, so must steer the discussions towards these points through subtle comments or targeted questions. This also requires careful selection of the recommended articles, where each article has appropriate depth and will lead the student presenter towards the key points intended for the class.

Such a discussion session is very different from classroom styles found in many engineering courses. Moving to such a session can initially be intimidating to an instructor who is used to more structured lecture styles. This instructor was initially quite nervous about the prospect of going into a class with no prepared lecture, with the plan that the students would actually engage in these targeted discussions for most of the class period. There were fears that the students either wouldn't participate at all, or else that the discussions would become out of control and not achieve the intended learning objectives. There were initially concerns by the instructor that he was not "doing his job" if he was not the one feeding information to the students. This highlights an issue that can hinder faculty adopting more interactive learning styles: the faculty must recognize that his or her value as an instructor is not necessarily just as the source of information conveyed via a lecture – that type of specific information can be provided in part through readings and assignments out of class. Rather, the more important value of the instructor is as one who leads students to discover knowledge and to engage in deeper thinking about material, and that this discovery and engagement can occur more effectively through targeted and led active discussions where the students must summarize, critique, compare, and contrast. We argue that the value of teaching students to think is greater than just the value of conveying information.

For an instructor who is more used to teaching in a conventional lecture style, transitioning to an interactive/discovery learning style of the classroom can be facilitated by techniques such as the randomized index cards that force students to be prepared for discussion, as well as the carefully selected topical targeted reading assignments. Since different students select different articles from the reading assignment list, then students have more comfort in presenting since they know that they will be sharing information that will be new to at least some of their classmates.

A final point should be made regarding the discussions. The instructor makes a strong effort not to preach a particular viewpoint, but rather to provide the students with information that will let them reach appropriate conclusions through the class discussions. This provides an openness to the classroom environment, where students don't feel that only the instructor has the right answers.

IV. Assessment and Outcomes

Feedback from the students has been very positive over the three terms the course has been offered. From student feedback available from Fall 2010 and Spring 2011 semesters, students rated the value of the class as 3.9 and 3.6 (on a 4.0 scale), with a teaching rating of 3.8 on a 4.0 scale each semester. In the student course evaluations each semester, eight course-specific outcomes are given. Students are asked to respond numerically to these outcomes, where 5.0 indicates strong agreement that the outcome was achieved, and a 1 indicates strong disagreement that the outcome was achieved. The results are shown in the table below.

Survey Question on Student Outcome	Fall 2010 (5.0 scale)	Spring 2011 (5.0 scale)	Fall 2011 (5.0 scale)
Describe basic concepts of energy and power, including types of energy, conversion of energy, and conservation of energy.	4.6	4.8	4.6
Understand the current mix of energy sources in use around the world, including coal, natural gas, oil, nuclear, solar, wind, geothermal, hydro, and biomass. For each of these, describe the basic technologies, the pros and cons of each, and the major challenges.	4.6	4.8	4.6
Understand the basics of electric power, including emerging issues of smart grid transmission and distribution.	5.0	4.8	4.6
Understand the basic environmental issues with energy generation and use.	4.8	4.6	4.4
Understand the basic policy issues of power and energy, including environmental regulation, pricing, and development.	4.8	4.6	4.6
Understand the basic economic aspects of power and energy, including energy markets.	4.5	4.6	4.2
Understand the relationships between energy use and economic activities, standard of living, and cultures.	4.6	4.6	4.4
Understand the basic geopolitical issues of power, including national security and economic security.	4.7	4.6	4.4

V. Summary and Future Issues

This paper describes a "Global Energy Issues" course that was developed to teach students about the political, societal, economic, and environmental aspects of energy as part of a multidisciplinary certificate in power and energy. As the course was developed, it was tailored to meet the requirements for a "Global Dynamics" course requirement within the university General Education curriculum, as a way of avoiding adding extra course hours to a student's curriculum. In a survey of member institutions of the American Association of Colleges and Universities (AAC&U), 78% say they have a common set of intended learning outcomes for all their undergraduate students, typically taught through a GenEd curriculum [7]. Some regional accreditation bodies -- for example, SACS -- also require a GenEd curriculum [8]. Although each university may have different requirements for GenEd, a survey of the American Association of Colleges and Universities identifies common themes, including science, global studies, technology, sustainability, and others [7]. We maintain that the class described can be tailored to meet a General Education requirement at many institutions. The course also is well suited for addressing the ABET expectations that students understand the broader impacts of engineering. Practically speaking, it is our claim that energy is also an excellent topic for extending STEM education into the realm of social, cultural, economic, environmental, ethical, and other domains. Energy is clearly a subject for scientific and engineering study, but it impacts people in very broad ways, from quality of life to environmental impacts to national security.

From the student evaluations and instructor perspective, the class has been successful. However, each of the three semesters that the course has been offered, the class has had under 25 students. The vast majority of students have been engineering majors (Mechanical, Civil, Electrical, Chemical, or Biosystems), but some students from agriculture, business, political science, biology, and other majors have also taken the course. Although the course has been approved by the university's General Education committee to satisfy the Global Dynamics requirement, the lengthy delay in the university approval process for a permanent course number means that the course has not been on the publicized list of General Education elective courses. Once the course does complete all administrative approvals for a permanent course number assignment, it will be identified to students as an option for their Global Dynamics requirement. At that time, it is expected that course enrollment will increase, both for engineering and non-engineering majors. Although class discussions and interactions can be difficult with larger classes, the structured discussion method (with the preassigned reading choices and the randomized selection of students via index cards) should be workable even to classes of 50 or more students.

Acknowledgements: This course is part of the Power and Energy Institute of Kentucky (PEIK) at the University of Kentucky, which is supported through a grant from the US Department of Energy, grant DE-OE0000409.

References

1. "Criteria for Accrediting Engineering Programs, 2012-2013: General Criteria 3 – Student Outcomes", from ABET website, http://www.abet.org/engineering-criteria-2012-2013/ , accessed January 2012.
2. *Energy at the Crossroads: Global Perspectives and Uncertainties*, by Vaclav Smil. MIT Press, 2005.
3. "Chinese Dam Projects Criticized for Their Human Costs", by Jim Yardley, New York Times, November 19, 2007. Available on the web at: http://www.nytimes.com/2007/11/19/world/asia/19dam.html?pagewanted=1&_r=1&ref=three_gorges_dam
4. "Quandary in the Amazon", by Clay Risen, Smithsonian magazine, March 2011. Available on the web at: http://www.smithsonianmag.com/people-places/A-Mega-Dam-Dilemma-in-the-Amazon.html (Internet title: "A Mega-Dam Dilemma in the Amazon")
5. "The Welfare Impact of Rural Electrification: A Reassessment of the Costs and Benefits", an IEG (Independent Evaluation Group) Impact Evaluation", The World Bank, Washington DC, 2008. Accessible on the internet at http://go.worldbank.org/QZGMM1PID0
6. "Japan asks workers to dress cool to save energy", by Tomoko A Hosaka, USA Today, June 5, 2011. Accessible on the internet at http://www.usatoday.com/money/world/2011-06-05-japan-dress-cool_n.htm
7. "Trends and Emerging Practices in General Education: Based on a Survey Among Members of the Association of American Colleges and Universities", Hart Research Associates, May 2009 http://www.aacu.org/membership/documents/2009MemberSurvey_Part2.pdf
8. "The Principles of Accreditation: Foundations for Quality Enhancement." Southern Association of Colleges and Schools (SACS), 2010. http://sacscoc.org/pdf/2010principlesofacreditation.pdf