Encouraging Sustainable Practices via Student Presentations

Paul J. Weber, Assistant Professor (pjweber@d.umn.edu)
Electrical and Computer Engineering Department
University of Minnesota Duluth

1. Introduction

Educating engineers for a sustainable future consists of enabling students to learn about sustainable engineering decisions. It also includes helping engineering students adopt sustainable learning practices. This paper discusses student presentations employed in lower level engineering courses that are designed to do both.

There were several learning objectives in the assignment of the presentations. The first goal was to help students understand current applications and/or technologies that embodied the theoretical class information. In order to do so, students were required to research topics of their own choosing and then communicate their findings to their peers, thus developing “soft skills.” The other central objective was for students to analyze the engineering design process *as a whole* rather than focusing on one aspect without examining the broader consequences. By examining the physical materials used, potential societal benefits of the product, and the practices of the manufacturing/sales companies, students were to study the impacts of these decisions and determine which would be sustainable. Furthermore, these objectives were carried out in such a manner that encouraged sustainable learning.

The remainder of the paper is organized as follows: Section 2 first describes the concept of sustainability and its importance. Section 3 then examines several attributes of sustainable learning. Section 4 follows with an illustration of the presentation guidelines and some of the pedagogical reasons behind them. Section 5 provides a discussion of the lessons learned from implementing the presentations and the inherent trade-offs of including such assignments in a course. Lastly, Section 6 describes possible improvements for subsequent classes and summarizes the paper and its contributions.

2. General Sustainability

The definition of sustainability is “a characteristic of a process or state that can be maintained indefinitely” (Jamaica Sustainable, 2007). For humans, a characteristic that is of growing concern is that of development—i.e. as individuals and as a race, we should be able to continue to develop and realize our potential. As a result, “sustainability” often refers to “sustainable development”, for which the generally accepted definition is “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (World Commission, 1987).

The number of future generations that current engineers should consider when making decisions is an issue of uncertainty. While previously four or five generations might have been sufficient,

recent research argues that since the effects of some pollutants from the industrial era have effects that can last hundreds if not thousands of years, the number should be significantly larger (Boyle & Coates, 2005; Tonn, 2004). If this approach is taken, engineers must go beyond the product life cycle towards the “project” life cycle which also includes the process (e.g. the factory and distribution techniques). The paradigm of the design process then must shift to examine not only the original system, but also change of that and other systems over time (Boyle & Coates, 2005).

While many categories could exist, sustainability is generally examined within the context of environmental, economic and social realms. The biosphere upon which the human race depends for basic life functions, resources and the disposal/assimilation of “waste” has a limited carrying capacity. Hence, humans must live in a manner that does not exceed that threshold for life to be *environmentally* sustainable. Similarly, a company must also be *economically* sustainable in order for the workers employed by the company to meet their basic needs. Lastly, decisions and technologies must be beneficial to society in a manner that enables humans to continue to develop *socially*. (Farrell, 1996; Wang & Lin, 2004)

The current mass production model of an economy in which increased growth is the desired attribute is not sustainable since the carrying capacity of the Earth is limited. While a simplified metric of how to achieve environmental sustainability is not agreed upon, current research suggests that humans need to cut their consumption of resources by at least a factor of ten (Boyle & Coates, 2005; Manzini, 1999). Furthermore, research indicates that the design phase of a project impacts 80% of its sustainability for each of the three subcategories (Charter & Tischner, 2001). As a result of these observations, adopting the concept of sustainability as a society and implementing sustainable design practices as engineers is crucial.

In order to achieve this, there has been research over the last decade into setting up guidelines for sustainability in the context of engineering decisions. In general, there are three key goals that have been identified (Boyle & Coates, 2005):

- To maintain the planet’s ability to provide basic life support functions, resources, and assimilation capacities;
- To enable equity within and between generations; and
- To take a holistic approach to solving problems.

Based on these and similar observations, research has been conducted to determine impact and sustainability indicators such that tools and target methods can be created and used as guidelines when making design decisions (Farrell, 1996; Gao, Zhou, & Wang, 2003; Dickinson, Mosovsky, Caudill, Watts, & Mnrahitto, 2002; Wang & Lin, 2004; Yang & Song, 2006).

3. Attributes of Sustainable Learning

In addition to sustainable design practices, it is also important to foster self-sustainable learning. As the above definition of sustainability mentioned, the chosen characteristic must be able to continue indefinitely. Thus, fostering sustainable *learning* can refer to aiding in the ability of students to learn throughout their entire lifetime—i.e. to become life-long learners. This is a

very important concept which has increasingly gained attention by those hiring employees in the industrial sector (Hawks, 1998).

There are many practices that can lead to sustainable learning. Several attributes that foster such learning are:

- Encouraging self-motivation in students;
- Enabling students to find and communicate information effectively;
- Improving the ability of students to reflect on their own learning history; and
- Increasing the understanding of a student's own learning strengths and weaknesses.

Such sustainable learning practices are akin to the old adage that if you give a person a fish, s/he will eat for a day, but if you teach a person to fish, s/he will eat for a lifetime (assuming the fish supply and techniques are sustainable!).

When examining the physical sustainability limits of learning systems, it is important to consider that cognitive learning generally pertains to the acquisition, manipulation, and application of information. In this context, the medium/technology through which the information is transmitted can impact the environment by the type and quantity of resources consumed, the amount of energy used, and the magnitude of the generated waste. There is also a financial cost to each of these metrics. Socially, learning needs to be done ethically and for a purpose that benefits society. These attributes (among others) lead to sustainable learning systems that are proposed as an evolution from mass production learning systems (Cheah & Cheah, 2002). A full discussion of such systems, however, is beyond the scope of this paper as only a couple of the attribute could be applied within the context of these presentations.

4. Presentation Objectives and Guidelines

Since the importance of understanding sustainability and human impact has been recognized (Bakshani & Allen, 1992; Broman, Byggeth, & Robert, 2002; Hesketh, Slater, Savelski, Hollar, & Farrell, 2004; Mott, Neff, Stratton, & Summers, 2002; ABET, 2007, p.2), it is imperative that instructors and institutions find ways to incorporate this need into their curriculum. This has been done in various ways (Diehl, Boks, & Silvester, 2005; Handy, French, & Jackson, 2005). While sustainability can be viewed as part of the design process, Richardson, Irwin & Sherwin argue that sustainability is an attribute of good design rather than a portion of it (2005).

The remainder of this paper is devoted to describing presentations and the corresponding insights gained from implementing them. It is important to note that they only served as an introduction to the concept of sustainability and an analysis assignment in the context of an application. In order for the students to more fully understand the process, a subsequent course in which the students had to *create* a sustainable design would also be required.

As stated in the introduction, there were several learning objectives in the assignment. The first goal was to help students understand where the class material is currently applied in commercial products and/or current technologies. In doing so, students had the opportunity to examine how the applications work, and learn the skills needed to conduct similar explorations in the future.

Furthermore, choosing their own topics increased the chance of developing self-motivation since it was more likely that the application would be something the students found interesting.

The second objective of the presentations was to help future engineers in developing the “soft skills” of researching given topics and then communicating their findings. The objective of doing so was to enable students to develop these sustainable skills rather than simply reiterating topics and techniques that were taught to them. Through this portion of the assignment, they gained experience using on-line and/or library resources to complete their research.

The other central purpose was to require students to think about the *entire* engineering design process instead of simply the technical aspects. This was achieved through research into the practices of the companies involved, including their location, the physical materials used, and the benefits that the product provides to society. The purpose of this was to encourage the students to examine the impacts of these decisions and determine which would be sustainable.

With these goals in mind, the following questions were given to the students to answer during their presentations. The questions provided a set of guidelines for the information to cover and defined one category of assessment for the work of the students.

1. Fundamentals of the Application: What is the application? Why is it important? Why do you find it interesting?
2. Course-Specific Questions: What role does [digital logic, circuit analysis] play in the application? What type of minimization would be appropriate? How was or would the [circuit, logic] be verified/tested?
3. Broader Impact: What companies manufacture the application? (Where are they located? Do they outsource manufacturing?) How sustainable is the design? (Can the components be re-used? Recycled? What is the material composed of?) What service does the application provide for the benefit of society?
4. Research: What are the limitations of the application? How could it be better? Is there research in the area currently going on to address these issues?

In addition to the goals listed above, there were additional reasons for the four groups of questions and their ordering. The top group of questions was listed first because it served as an introduction to let the audience know what the topic was and provide motivation to listen. The second topic provided a smooth transition into the technical aspects since it expounded on the very first question of what the application was. Once the application had been explained, the broader impacts could then be explored. Lastly, it is important for students to understand that there are always limitations and trade-offs in designing products. Hence, that topic was explored by the fourth group of questions.

In order to assess the work of the students, a matrix was created with five headings, each with the grading of [sufficient (1 point) | marginal (0.5 points) | Unacceptable (0 points)]. The categories were chosen as:

- Time: Students were allotted 8 – 10 minutes for the presentations and were graded on whether they were [within the time frame | within 30 seconds per person | short or long by more than 30 seconds per person].
- Topic Questions: Students were graded on whether they answered [all questions listed above | all but 1 or 2 questions | fewer than 9 of the above questions].
- Citations: Students were required to supply the instructor with at least three references pertaining to the application and were graded on whether they [obtained at least three relevant references | included non-relevant references | omitted the references].
- Visual Aids: Students were instructed to use visual aids but the specific type(s) were not mandated. They were assessed on if the aids were [well organized, supplemental to the speakers, and not distracting | cluttered, read directly from by the speaker(s), and/or distracting | not used at all or did not relate to the application].
- Public Speaking Skills: Five subcategories were given to the students indicating positive attributes of effective public speaking. These were:
 - Eye contact is made with the audience;
 - Speaker enunciates words and is easy to hear but not overly loud;
 - Speaker has positive body language and gestures—e.g. minimizes fidgeting;
 - Transitions between slides and/or thoughts are smooth;
 - There is minimal use of non-word slurs—e.g. “uh, um”;
 Students were assigned points according to whether they had problems in [none or one subcategory | two or three subcategories | four or all of the subcategories listed].

Even though many more are possible, these categories were chosen because they included the major points of presentations in general and the learning objectives of the specific assignment. In addition to technical questions, time was chosen because there will often be a (sometimes implicit) time frame which is important to adhere to, especially when others also will be speaking at the same gathering. In addition, citations were included to stress the fact that when communicating the ideas of other people, the audience needs to know the source so they can check the validity and/or assumptions if they desire to do so. Visual aids were assessed due to the fact that they can greatly enhance a presentation or have just the opposite effect by detracting attention from what is being said. Lastly, public speaking was incorporated to stress positive verbal and physical attributes of effective communication.

There are three main pedagogical reasons for employing the use of a grading matrix. First, it is intended to foster effective communication of expectations to the students. Secondly, it increases the objectiveness of the score by describing a specific set of grading criteria. Lastly, it enables timely feedback which has increases the likelihood that students will make positive adjustments for presentations in the future. The main disadvantage of using such a rubric is that it hinders the flexibility when distinguishing between grades—i.e. it forces the same deduction for two groups with the same fault but varying degrees.

The presentations directly addressed the first two bullets describing sustainable learning attributes in Section 3. By allowing students to select the current application, the chance of increasing their self-motivation within the area was enhanced. In addition, by specifying that the students must perform the research, their ability to find information for this and subsequent endeavors was improved.

5. Outcomes and Discussion

While the presentations were well received and well executed by most groups, there was no formal analysis of the outcomes. Furthermore, due to time limitations of the semester, each student only took part in a single presentation. Hence there was no opportunity to gauge improvement in terms of the oratory and investigative skills of the students. As a result, what follows are mostly qualitative comments based on observations.

One observation is that the amount of time specified by this particular set of guidelines was a more noticeable constraining factor in the information they chose to convey to their peers. There is always a trade-off between the amount of detail that can be explored and the amount of time it takes to do so. As a result, groups either exceeded the time limit when trying to provide greater detail or had to minimize depth in order to satisfy the objective.

Another comment is that a number of the groups did not have a good grasp on how the theory from the class related to application. It is interesting to note that for one of the courses, examples from the previous semester were provided when choosing topics. Overall, that class performed better in addressing the theoretical concepts embodied by their specific application. The potentially negative effect of such examples is that they could hinder the diversity of topics chosen (that fortunately did not happen in the particular course, however).

The last general remark is that the majority of students did not have an intuitive understanding of sustainability prior to the project. Furthermore, the word “sustainability” in the guidelines effectively referred to “environmental sustainability” even though social sustainability was also addressed in another question. As a result, many students struggled when examining that portion of the application. To avoid this, the instructor should clarify the definition of sustainability before-hand, as well as any other terms that can have varying definitions depending on their context. Instructors who do so will also become more familiar with the concept under consideration.

There are several general advantages of implementing such presentations in a class. A major advantage is that they provide an opportunity for students to gain experience in the research and communication of information to their peers that a traditional lecture would not permit. Another positive effect is that students are able to choose their applications, which often increases their self-motivation to learn about the topic. Furthermore, by specifying current technologies, the relevance of the material is increased and it provides an opportunity *for the instructor* to learn about the newer applications also.

Employing the presentations as a portion of a course also includes inherent disadvantages. The most significant drawback is that the presentations consume a considerable amount of time. For

this particular course, there were 10 groups of four students each which led to using approximately two to three class periods of time (~5 – 7% of the class in a 15-week semester). With this in mind, it is imperative that the instructor minimize transitions. This can be done by having students send materials ahead of time or arriving slightly early to setup and presenting at the beginning of the class period.

6. Future Improvements and Summary

Several aspects of the presentations could be improved on for subsequent classes. The primary weakness of the current design is that there was no incentive for the audience (i.e. the remainder of the class) to pay close attention. While this was not generally a problem at the beginning of the presentations, as the speakers progressed more and more of the students lost interest. This was mostly likely caused by the presentation and/or the choice of material—e.g. if the material was highly technical without adequate visual aids, it was hard for the audience to grasp the concepts. Student presentations were spread out over the course of the semester to minimize the loss of audience attention due to too many groups on a given day, but there is still a need to increase participation in the future. One possible solution is to have the students critique the presentations of their peers. In addition to encouraging better listening, this would also potentially enhance their ability to reflect on their own presentation skills.

The second portion of the assignment that could be enhanced is the definition and understanding of sustainability. For this purpose, it would be possible to assign one or several articles that clarify what sustainability is and list some examples of companies that use sustainable practices and/or produce sustainable products. An alternative to this would be to have a group discussion on the topic if there was ample in-class time to do so. Regardless of the approach, the difference between general sustainability and the three subcategories should be adequately addressed.

Another improvement would be to *quantitatively* assess the effectiveness of such presentations in achieving their goals. The first topic that would be useful to gauge is the effectiveness of such introductions to the sustainability concept. This could be measured by surveying the students about the topic both at the beginning and end of the course. In addition to this, it would be informative to view the correlation (if any) between the primary theoretical topic for each group and the performance of those students on quiz or exam questions pertaining to that same concept.

The last improvement would be to require the use of technical material such as journals and manuals as a portion of their references. While a few did use technical sources, the vast majority of references came from links such as www.howstuffworks.com and www.wikipedia.org. While these sites often are very effective at illustrating basic definitions and functions of a product, they are potentially less reliable and do not always provide as much technical depth.

Educating engineers about sustainable design decisions is crucial to ensuring that humanity does not exceed the carrying capacities of the biosphere while allowing businesses to be profitable and individuals to realize their potential. Encouraging sustainable learning practices is also critical to enable students to adapt and continue to learn effectively well beyond their years in higher education. The student presentation described herein have great potential to aid in both of these areas as well as helping students develop the “soft skills” of research and communication. As a

result, such presentations provide an option for instructors looking to integrate these goals in a manner that fosters self-motivation and technological relevance.

References

- ABET Engineering Accreditation Commission (March 18, 2007). Criteria for accrediting engineering programs. Retrieved June 30, 2007, from <http://www.abet.org/Linked Documents-UPDATE/Criteria and PP/E001 07-08 EAC Criteria 11-15-06.pdf>
- Bakshani, N., & Allen, D.T. (1992). Pollution prevention education at universities in the United States. *Pollution Prevention Review*, 3 (1), 97.
- Boyle, C., & Coates, G.T.K. (2005). Sustainability principles and practice for engineers. *IEEE Technology and Society Magazine*, 24 (3), 32 – 39.
- Broman, G., Byggeth, S., & Robert, K. (2002). Integrating environmental aspects in engineering education. *International Journal of Engineering Education*, 18 (6), 717 – 723.
- Charter, M., & Tischner, U. (2001). *Sustainable solutions: developing products and services for the future*, Greenleaf Publishing, Sheffield, UK.
- Cheah, H.-B., & Cheah, E. (2002). Towards sustainable learning. *Proceedings of the International Conference on Computer in Education*, 1, 569 – 573.
- Dickinson, D. A., Mosovsky, J. A., Caudill, R.J., Watts, D.J., & Mnrahitto, J.M. (2002). Application of the sustainability target method supply line case studies. *IEEE International Symposium on Electronics and the Environment*, 139 – 143.
- Diehl, J.C., Boks, C., & Silvester, S. (2005). The evolution of design for sustainability courses. *Fourth International Symposium on Environmentally Conscious Design and Inverse Manufacturing*, 78 – 85.
- Farrell, A. (1996). Making decisions about sustainability: joining social values with technical expertise. *Proceedings of the International Symposium on Technology and Society Technical Expertise and Public Decisions*, 188 – 197.
- Gao, M., Zhou, M.C., & Wang, F.-Y. (2003). Improvement of product sustainability. *Proceedings of the IEEE International Conference on Robotics and Automation*, 3, 3548 – 3553.
- Handy, R.G., French, R.M., & Jackson, M.J. (2005). Introducing environmental sustainability in a manufacturing processes course. *Proceedings of the 35th Annual Conference on Frontiers in Education*, S1D, 7-9.

- Hawks, V. (1998). A perspective from industry on characteristics of life long learning. 28th *Annual Frontiers in Education Conference*, 2, 743 – 747.
- Hesketh, R., Slater, C., Savelski, M., Hollar, K., & Farrell, S. (2004). A program to help designing courses to integrate green engineering subjects. *International Journal of Engineering Education*, 20 (1), 113 – 122.
- Jamaica Sustainable Development Network. Glossary of terms (2007). Retrieved June 30, 2007, from <http://www.jsdnp.org.jm/glossary.html>
- Manzini, E. (1999). Strategic design for sustainability: towards a new mix of products and services. *Proceedings of the 1st International Symposium on Environmentally Conscious Design and Inverse Manufacturing*, 434 – 437.
- Mott, R., Neff, G., Stratton, M., & Summers, D. (2002). Future directions for mechanical, manufacturing, and industrial engineering technology programs. *Journal of Engineering Technology*, 91 (2), 8 – 15.
- Richardson, J., Irwin T., & Sherwin, C. (2005). Design and sustainability. *A scooping report for the sustainable design forum*.
- Tonn, B.E. (2004). Integrated 1000-year planning. *Futures*, 36 (1), 91 – 108.
- Wang, L., & Lin, L. (2004). Making sustainability accountable: a valuation model for corporate performance. *IEEE International Symposium on Electronics and the Environment*, 7 – 12.
- World commission on environment and development (1987). *Our Common Future*. Oxford, U.K.: Oxford Univ. Press.
- Yang, Q.Z., & Song, B. (2006). Eco-design for product lifecycle sustainability. *IEEE International Conference on Industrial Informatics*, 548 – 553.

PAUL J. WEBER is a Temporary Assistant Professor at the University of Minnesota Duluth. Since completing his Ph.D. at Michigan Tech in 2006, he has taught Electric Circuit Analysis and Digital System Design, in which these presentations were implemented. His primary research interests are renewable energy systems and fault tolerance.