The Sustainable Classroom: Teaching Sustainability to Tomorrow's Engineers[1]

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INTRODUCTION

Why is an education in Sustainable Engineering needed and what should it look like? Engineers play a central role in creating infrastructure in the world by acting as problem solvers who apply their knowledge and experience to projects that meet human needs. They work on a wide range of issues and projects, and as a result, how engineers work can have a significant impact on progress toward sustainable development. How engineers are educated has a significant effect on the way in which they work and the way in which they understand their role in sustainability. This paper explores one way in which engineers can to be educated in sustainability—service-oriented learning.

BACKGROUND

Sustainability is slowly but surely finding its way into university curricula. An overview of the progress from 1992 to 1997 is contained in the report *The Engineer's Response to Sustainable Development*, dated February 1997, and published by World Federation of Engineering Organizations (WFEO). In the US many engineering colleges have developed extensive programs with special courses on the environment and sustainable technologies. Internationally, other institutions have also integrated these concepts into their courses.

In 1999, the American Society for Engineering Education (ASEE) approved a statement on the need for education in engineering sustainability. The statement reads: "Engineering students should learn about sustainable development and sustainability in the general education component of the curriculum as they are preparing for the major design experience." For example, studies in economics and ethics are necessary to understand the need to use sustainable engineering techniques, including clean technologies. In teaching sustainable design, faculty should ask their students to consider the impacts of design upon U.S. society, and upon other nations and cultures. Engineering faculty should use systems approaches, including interdisciplinary teams, to teach pollution techniques, life cycle analysis, industry ecology and other sustainable engineering concepts.

Case studies, including studies of university-industry-government partnerships, can be used to illustrate the importance of the multidisciplinary aspects of designed systems, the impacts of those systems upon society and the environment, and the practical viability of the sustainability concept.

Sustainability is even being pushed in engineering accreditation. The organization responsible for coordinating this process—the Accreditation Board for Engineering and Technology

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(ABET)—in their document Engineering Criteria 2000 states that students must be prepared for professional practice through a curriculum that includes "most of the following considerations: economic, environmental; *sustainability* [italics added]; manufacturability; ethical, health and safety; social; and political." In part due to ABET, many US universities are beginning to introduce the principles of sustainable development into their curricula.

ASEE in 2002 indicated that engineering graduates must be prepared by their education to use sustainable engineering techniques in the practice of their profession and to take leadership roles in facilitating sustainable development in their communities.

WHAT IS SUSTAINABILITY?

Unfortunately, there is not a clear consensus on what the meaning of sustainability is in engineering (or even in conservation biology[1,2]). For example, the question of what represents a sustainable engineering structure or system is still an open-ended question that needs to be addressed and clarified by engineers. While this may seem problematic, it may permit the student to be more involved in creating this meaning through discussions with many parts of the engineering community. Sustainability of new development of infrastructure or industrial goods is commonly the issue considered in education. Some of the definitions of sustainable development are:

1. The World Commission on Environment and Development's (WCED) widely used definition of sustainable development is: "Meeting the needs of the present without compromising the ability of future generations to meet their own needs."
2. "Sustainability means living, working, and behaving in a way that will sustain the integrity and biodiversity of the local, regional, and planetary ecosystems on which all life depends. It means finding ways to achieve the quality that we seek in our own lives without sacrificing the quality that Earth's many and varied ecosystems need." Guy Dauncey
3. "Growth without cheating our children. Improving the quality of life for all without damaging the environment or the ability of future generations to meet their own needs." Sustainable Gloucestershire produced by Vision 21
4. "The future will be green, or not at all. This truth lies at the heart of humankind's most pressing challenge: to learn to live in harmony with the Earth on a genuinely sustainable basis." Sir Jonathon Porritt
5. "We must learn what sustainability means in practice if we are to apply it to our daily lives and restore the health and vitality of our planet." Sir David Attenborough
6. "There must be a better way to make the things we want, a way that doesn't spoil the sky, or the rain or the land." Sir Paul McCartney
7. We need to work toward "… a delightfully diverse, safe, healthy and just world, with clean water, clean air, clean soil and clean power – economically, equitably, ecologically and elegantly enjoyed." William McDonough

Although these definitions illustrate the variety of opinion regarding the concept of sustainability, several themes are evident:

- Inter-generational and intra-generational equity – accepting that the current generation should not leave a degraded environment for the next generation, and recognition that equity within the present generation is a legitimate and necessary goal
- Integration of the economy and the environment – acknowledging the linkages between the health of both the economy and the natural environment
- Dealing cautiously, yet anticipatory with risk, uncertainty and irreversibility – adoption of the precautionary principle with respect to potential impacts
- Conservation of biological diversity – maintaining the variety of life forms and ecological integrity
- Recognition of the global dimension – accepting that the impacts of national, state and local policies and activities are not spatially or temporally confined.

Compounding the difficulties of educating about sustainability are the troubles engineers have in deciding how science is properly joined with nonscientific factors to formulate an overall goal. It is widely understood that we cannot jump from the "is" of unaltered nature to the "ought" of sustainability. Science's role is very limited with respect to the specific task of setting a normative goal. A well-considered goal would take into account human utility, ethical and religious considerations, and the limitations on human knowledge and powers. Many of these concepts stem from a world view. It is critical for engineers to understand their own and others' world views in order to dialogue about the *when* or *oughtness* of a design. It is clear that engineers of the 21st century will be called to make decisions in a professional environment where they will have to interact with others from many technical and non-technical disciplines. Thus, they will need to be given the proper skills to think and act in a more holistic manner. They will need to develop a single worldview from which life is lived. Questions such as the following will need to be pursued[3]:

- What is prime reality – the really real?
- What is the nature of external reality, that is, the world around us?
- What is a human being?
- What happens to a person at death?
- Why is it possible to know anything at all?
- How do we know what is right and wrong?
- What is the meaning of human history?

The decisions about the development and deployment of technology are not made by the technology but by people; the decisions are therefore not just "technical" but include a clear ethical dimension. If students are merely taught *how* to design but not *what* or *when* to design, the education of these students is woefully incomplete.

It is apparent that science and engineering cannot possibly solve all societal problems. If engineering is to be a strong interlocutor in the dialogue about the future, it needs to become more integrated with science, society, and humanistic concerns[4]. Social, political, economic, cultural, ethical, and even theological issues must be addressed side by side with technical issues. Indeed, such non-technical issues can be even more important than science and engineering. In some cases, the best overall decisions may not be the best technical one. As a result, engineers of the 21st century will have to work in an environment that is more multi-disciplinary and interdisciplinary than ever before. Engineers will also need to contribute to the improvement of technological literacy for the general public. If the interdependence and balance of technological prowess with democracy falter, if technology becomes dominant, or if democracy does not support technology--as well might happen if the citizens are technologically illiterate--the system that is a beacon of hope for the rest of the world will crash[5].

NEED FOR A HOLISTIC PERSPECTIVE

It also seems that the goal of any curriculum should be to educate for life, not just thought. It is important for the life of the community that individuals study not just for themselves but for the good of the community. A great many occupations today are such that if one is to work in them successfully he or she must acquire a more or less thorough knowledge of the various disciplines. Traditionally this was true of those occupations known as the learned professions-law, medicine, diplomacy, and the ministry. But today, an education at the university level is regarded as an indispensable requirement for successful work in many more occupations. But something is lacking. More than study is needed. What is missing is the need to energize a student to live out the values of the community, to support the community, to assist it to grow and prosper, to improve it, to not only consume but to give. How can education do that? If the community as a whole is to do its work, in our knowledge-hungry world, it will be useful, if not indispensable, for a rather large proportion of the members of the community to be acquainted with the academic disciplines. But to say that is to say something quite different from saying that such acquaintance will incline, dispose, energize students so to live to support the community. To desire to support a community, one must understand the values of the community, hold similar values and desire the health of the community[6].

Unfortunately many of today's universities are ill equipped to teach their students who will broker the power of technology tomorrow. What is the purpose of an engineering education? On the one hand, there is the conviction that the engineering student should be introduced to scholarship. She should be instructed in depth in a single engineering discipline, should develop some practice in research techniques and investigative procedures, should master the basic literature in a field, and should learn the special, if limited, value of a technical vocabulary. In short, engineering education should strive to produce specialists, and should therefore derive its central, if by no means it's only, content from the program for graduate students. This may be called the *scholastic* conception of engineering education.

On the other hand, there is the view that engineering education should be devoted to broadening and deepening the lives of its students. It should introduce them to the value-tradition on which our society is established. It should remove their provincialism, so that they learn how to appreciate alien cultures and strange behavior. It should expand their sensitivities, initiating them to the beauty of art as well as to the clarity of science. In short, by enriching their humanity, engineering education should aim to produce *leaders*, who will contribute a broadly sensitive and highly self-conscious awareness, to whatever community they may serve. This may be called the *humanistic* conception of engineering education.

Note that both the scholastic and humanistic conception focus entirely on academics, to the ignoring of the actual social issues we must all face: issues of justice and injustice, of freedom and coercion, of peace and hostility, of stability and chaos, of poverty and wealth, of racism and dignity. Of course it's true that several of the other academic disciplines focus their study on society. But developing social or political or economic theory is different from asking what must be done about the ethical issues confronting us in society. If engineering is a profession that promotes a theme of a healthy society, then young engineers need to be taught to scrutinize society to see where it falls short of what ought to be, must ask what, if anything, can be done to bring it closer to what it ought to be, and must then start doing that.

If we seriously believe that the goal of education is not just to equip students to live lives but also to inspire and energize and marshal them to support the community, that the goal is to contribute to their moral and spiritual formation (which is the only plausible motif from which values arise), then we have to reflect on how we can make responsible use of these a-rational factors, and how we can make responsible use of reasoning from principles to applications of principles. Developing the latter would, for one thing, require much more praxis-oriented scholarship than the scholastic model calls for.

It's clear that from such reflections as these take us beyond curriculum into pedagogy, about which we as a community have reflected very little. Indeed, they take us into a consideration of institutional structures. We as faculty members would prefer that our educative impact be confined to what we say in classrooms, but the truth is that our entire comportment is educative- and beyond that, the comportment of the entire institution is educative. If the registrar treats the students with consideration, that teaches something. If the buildings we teach in are not designed for low-energy use and more use of natural light[7], our students are hearing our values loud and clear.

Of course the recurring theme of customer-based engineering education will come back to equipping our students for jobs. But that's not the final point of university education. The reason is that as humans we shall still have to ask what those jobs themselves are for. How will the job I'm preparing for serve other people? How will it clean a lake instead of polluting one? How will it offer opportunity to marginalized people rather than crowd them still further out to the rim of things? How will it yield an honestly built product or genuinely useful service? In other words, how will the knowledge, skills, and values of my university education--how will these things be used to clear some part of the human jungle, or restore some part of the lost loveliness of this world, or introduce some novel beauty into it? That is, how does my education and work make for sustainable peace (in Hebrew shalom)?

In our reflections, we begin to see that the wounds of the world scarcely enter our curriculum. We talk abstractly about justice and injustice; but we do not look much at concrete cases of injustice, probing their causes and asking what can be done. Or at least, the scholastic model of the curriculum does not invite us to do this. Engineering educators have been able to abstract themselves and the curriculum they teach from such issues. Mostafa Tolba, Chairman of the Commission on Sustainable Development, commented the following "Achieving sustainable development is perhaps one of the most difficult and one of the most pressing goals we face. It requires on the part of all of us commitment, action, partnerships and, sometimes, sacrifices of our traditional life patterns and personal interests." We, as educators, will need to model for our students “commitment, action, partnerships and, sometimes, sacrifices of our traditional life patterns and personal interests.”

AN ALTERNATIVE—ENGINEERS WITHOUT BORDERS

Building these themes into an engineering faculty and an engineering curriculum is a major challenge for universities. One of the most promising tools we have available is found in service-learning. A further refinement of service-learning as it pertains to “commitment, action, partnerships and, sometimes, sacrifices of our traditional life patterns and personal interests” in engineering is embodied in the organization Engineers Without Borders (EWB).

EWB’s mission is to help disadvantaged communities improve their quality of life through implementation of environmentally and economically sustainable engineering projects, while developing internationally responsible engineering students. EWB’s outward vision is of a world where all people have access to adequate sanitation, safe drinking water, and the resources to meet their other self-identified engineering and economic development needs. The business of EWB is to engage a developing community in resolving a particular infrastructure need (or needs) that the community itself has identified. EWB involves student engineers in every step of the EWB process, enabling them to learn firsthand about the application of engineering solutions to the problems of the developing world. By bringing together engineering faculty and students in these activities which will touch the wounds of the world, it will stretch both the educator and the educated in “commitment, action, partnerships and, sometimes, sacrifices of our traditional life patterns and personal interests” that will truly make for shalom in a world that so desperately needs it.

The EWB experience requires engineering students who have been raised and schooled in a developed world perspective to see a need for technologies that are not always the latest but are most appropriate in these settings. By living for a period of time in a developing community, these students are not just confronted by an academic exercise but begin to understand the necessity of arriving at good, sustainable solutions for these communities. They gain a perspective on their own culture, values, and technology by having to examine them through another lens. They are challenged to understand their role, both in-country and back home, at closing the gap between the haves and the have-nots. They begin to ask questions. What if every person on earth lived with the developed world ecologic footprint? Will workers be displaced by the introduction of this new technology? How can deforestation be reduced when basic fuel for cooking is needed every day? They are required to evaluate the use of technology from the local social, environmental and economic conditions. Through challenges like these, an EWB student realizes they can meet actual community needs with the full collaboration of the community using their skills and with a sense of care and desire to improve the quality of life for the community.

UNIVERSITY OF WISCONSIN EWB CHAPTER

At the University of Wisconsin, we have a very active EWB chapter. The first author serves as the chapter’s faculty advisor. We have over 100 student members and participate in semi-annual service trips.

Students went to strife-ridden Rwanda during the summer of 2004 and early winter of 2005 to assist in installing a reliable water system. The country has been torn apart by a civil war, and is one of the poorest of African countries. Rwanda has little working infrastructure, and basic necessities like clean water and sewage systems are lacking in much of the country. Because the country is so poor, communities have to rely on rudimentary water systems. Villagers are often forced to walk several miles to obtain water if their local system breaks down, and often that water is untreated.

The UW-Madison EWB chapter focused its efforts on the Muramba Deanery, an area of about 300,000 people. Muramba is one of the poorest areas of Rwanda and has received little government assistance in building up its basic infrastructure system. In the summer of 2004, nine members of the UW-Madison EWB chapter along with the first author traveled to Muramba to work on local projects for two weeks. The group of students worked on improving a gravity-fed water system that supplies much of the water for Muramba. Because of the country's extremely mountainous terrain, it's difficult to build centralized water systems. So drinking water has to be found and delivered locally. In addition to working on the gravity-fed water system, the group of students has worked with Muramba residents to encourage them to develop practical skills, such as welding and pipe-fitting, that will help sustain the water system and other improvements.

The students were overwhelmed by the welcome reception they received from the Muramban residents. The local people embraced the work of the students, dedicated themselves to building on the group's projects, and urged them to come back. According to one student, "Rwanda is both beautiful and terrible . . . . It has terrible, gripping poverty and a legacy of war and genocide. People survive in terrible conditions . . . . In my opinion, the most important thing we did was build a relationship with this community that will serve as a foundation for future interactions."

The EWB activities have led to the creation of a 3-credit course on sustainability. This course was offered in the Spring of 2005.

SUMMARY

Engineers will need to play an increasing role in the promotion of a sustainable society. How engineers are educated has a significant effect on the way in which they work and they way in which they understand their role in sustainability. This paper explored the need for engineers to be educated in sustainability. One means to facilitate sustainable learning is via service-based projects. EWB provides an excellent vehicle to enable a deeper appreciation and understanding of sustainability principles.

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