AC 2008-766: ENGINEERING, PEACE, JUSTICE AND THE EARTH: DEVELOPING COURSE MODULES

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Abstract

An effort to reform engineering to meet the challenges of peace and security, poverty and underdevelopment and environmental degradation and sustainability is proposed. Faculty and staff at institutions both within the United States and Canada have worked collaboratively to develop course modules. The present effort is in the first year of a three year effort funded by the Pennsylvania/New York Consortium, under the Learn and Serve America Program within Campus Compact.

Introduction

According to the Worldwatch Institute in their annual report on the state of the world, we face three interrelated challenges: the challenge of security, including risks from weapons of mass destruction and terrorism, the challenge of poverty and under-development; and the challenge of environmental sustainability.[i] Technology and rapid accelerating technical advances have played key roles in the creation of these challenges. Thus, engineers and the profession of engineering have much to say as to whether or not the challenges of security, poverty and sustainability can be successfully met.

Vesilind[ii] noted that engineering from its inception has been intimately associated with waging war. The earliest engineers were military engineers who worked at the behest of leaders who either were leading conquering armies or defending their conquered lands from invasion. Vesilind makes reference to the British linguist Young who in 1914 described the lineage of the word engineer tracing it back to the Latin word *ingenium*, an invention or engine.[iii] Young adds, "There must have been confusion of Latin *ingenuus* and Latin *ingeniosus*. These should be opposite in meaning. I suppose an engineer ought to be ingenious and ingenuous, artful and artless, sophisticated and unsophisticated, bond and free." Vesilind concludes with a description of the dichotomy that he claims captures the essence of engineering today.

> "The engineer is sophisticated in creating technology, but unsophisticated in understanding how this technology is to be used. As a result, engineers have historically been employed as hired guns, doing the bidding of both political rulers and wealthy corporations."[iv]

According to the Social Summit Programme of Action, "Poverty has various manifestations, including lack of income and productive resources sufficient to ensure sustainable livelihoods; hunger and malnutrition; ill health; limited access or lack of access to education and other basic services; increased morbidity and mortality from illness; homelessness and inadequate housing; unsafe environments; and social discrimination and exclusion. It is also characterized by a lack of participation in decision-making and in civil, social and cultural life. It occurs in all countries: as mass poverty in many developing countries, pockets of poverty amid wealth in developed countries, loss of livelihoods as a result of economic recession, sudden poverty as a result of disaster or conflict, the poverty of low-wage workers, and the utter destitution of people who fall outside family support systems, social institutions and safety nets." It further emphasizes that "Absolute poverty is a condition characterized by severe deprivation of basic human needs, including food, safe drinking water, sanitation facilities, health, shelter, education and information. It depends not only on income but also on access to social services."[v] Notably, Vallero describes engineering as becoming increasingly complex and the responsibilities of engineers to society as changing as society evolves. [vi]According to Vallero, the great challenge in engineering is to treat all people fairly and justly.

The challenge of environmental sustainability results from a wide-ranging list of critical issues. A few examples of the urgency associated with sustainability are described. Concentrations of carbon dioxide, the main global warming gas in the Earth's atmosphere, posted the largest two-year increase ever recorded. Studies note that if the global temperature rises 2-6 degrees as now predicted, up to 35% of the world's species would become extinct by 2050. [vii] The United Nations published a study noting that the number of oceans and bays with "dead zones" of water, so devoid of oxygen that little life survives, has doubled to 146 since 1990. [viii] Two thirds of Caribbean coral reefs are threatened by human activities, including over-fishing and pollution runoff from agriculture. Toxic metals from discarded cell phones threaten both groundwater and he health of recyclers in Pakistan, India, China and elsewhere.[ix] Polar ice caps and mountain glaciers are experiencing rapidly increasing temperature and as a result are melting at an accelerating rate. The Arctic Climate Impact Assessment study released in 2004 estimates that the Arctic Ocean might be ice-free by the end of the 21st century.[x] The ice sheets covering Greenland and Antarctica are seriously weakening and in many instances disintegrating. This disintegration would cause raising ocean levels around the world and concurrently significant flooding of coastal areas.

The world is in the midst of a period of unprecedented and disruptive change. This is particularly evident when examining the health of the world's ecological systems. A host of human forces impinge upon coral reefs, tropical rain forests and other critical natural systems located around the world. Half the planet's wetlands are gone. Total carbon emissions and atmospheric concentrations of carbon dioxide are both accelerating and 2004 was the fourth warmest year ever recorded. Over the course of the last 120 years, the ten warmest years have all occurred since 1990.

The question then becomes how can the engineering profession effectively respond to these three challenges, that is, to the challenge of peace, of poverty and under-development, and of environmental sustainability? Realities of the present engineering curricula prevent the possibility of additional courses. Rather, today the emphasis in undergraduate engineering is reducing the number of credit hours required to earn a degree. We propose to develop a series of course modules for a variety of different engineering disciplines that will focus attention on the three important challenges and nurture the development of both analytical skills and compassion in students and future engineers to effectively deal with the problems of peace, of poverty and of environmental degradation.

A. Approach

Our stated goal is to develop a series of course modules which can be used by engineering faculty in various disciplines which focus on meeting the challenges of peace and security, poverty and underdevelopment, and environmental degradation and sustainability. We are working with selected and interested engineering organizations that have been identified by the campus service-learning coordinators. In the development effort in of the modules, we have focused upon answering the following set of questions on the nature of engineering:

- What does engineering look like which contributes to peace, social justice and environmental sustainability?
- What drivers are there for current engineering practice?
- What examples exist that can be framed as learning objects?
- How can we learn from the historical examples of the relation between engineering, society, and the environment?
- What political, social and economic frameworks support an engineering practice that promotes peace, justice and sustainability?
- What effect does globalization have on the potential of engineering?

Our philosophy in developing course modules can be illustrated in the following example. Consider the case of a mechanized fruit picker. Harvesting machines are replacing migrant workers as grape pickers in northern California.[xi] Today, such machines cost approximately $126,000. It takes five workers about eight hours to pick 10 tons of grapes. To harvest the 100 tons would require 90 workers if they wanted to be done before sun-up. The costs are relatively straightforward to calculate. It costs $120 a ton to harvest by hand, and $30 a ton by machine. A mid-size wine producer expects to harvest about 4,000 tons of grapes total. For 4000 tons, the cost to pick the grapes by hand is approximately $480000 while the costs using a harvester are $120,000 representing an increase in margin above cost equal to $340,000. Even with the cost of the harvester subtracted from this margin, the net increase in profits is equal to $204,000.

Traditional engineering discussions might stop here. But what if we go a bit farther and identify the workers as being part of the community? What else would we be forced to consider? If it takes 90 workers to harvest 100 tons then it would take the equivalent of 3600 workers to harvest 4000 tons. Certainly there are many more people involved than simply the workers themselves with the total involved growing far beyond the estimate of 3600. What will become of them? Should we as the engineers who designed, built, tested, evaluated and delivered the harvester care? What should the responsible engineer do? Today, there is virtually no consideration given to the workers whose livelihoods have been eliminated. An engineering that integrated analytical skills and compassion might suggest a very different result as it forces us as engineers to consider the entire living system, in this case, including the men, women and children who toil as grape pickers and whose quality of life is intimately linked to the harvest.

For this case, the following questions concerning the significance of the grape-harvesting device may be asked:

- For whom should the device be designed? The owners? The land? The workers? Someone else?
- What will become of the displaced workers?
- What will become of the displaced workers families?
- Are there long-term effects on the land?
- Are there societal implications for the workers' communities?

- Are there societal implications for the greater community outside the workers and their families?

In the context of the farm workers discussed here, a logical question to ask would be the following: Is it possible to arrive at an end result which was a creative design that met everyone's needs and established justice for workers and their families and furthered the interests of the vineyard? While we cannot offer a device, we can suggest that those whom the new machine would make irrelevant might be included in discussions concerning the consequences of implementing the new design. The landowner may ultimately decide to mechanize this task but at the very least the criteria for making ethical choices would also include a careful consideration of the impact of the engineering design on the lives of the workers. It would seem such an inclusion is as important as any other. Such a module could be used in engineering courses in statics and dynamics, control systems, engineering economics and engineering design. Our effort in the proposed effort is to develop similar course modules in a wide range of engineering subjects.

B. Course Module Examples

Several course modules have been developed with approximately ten more to be completed in the following two years. A listing and brief discussion of the existing modules are presented.

<u>Module 1: The Gini Coefficient and Poverty in the U.S</u>

This assignment is completed in the form of a Gini coefficient which is a measure of statistical dispersion most prominently used as a measure of inequality of income distribution or inequality of wealth distribution. It can be used to compare income distributions across different population sectors as well as countries, for example the Gini coefficient for urban areas differs from that of rural areas in many countries (though the United States' urban and rural Gini coefficients are nearly identical). It is sufficiently simple that it can be compared across countries and be easily interpreted. The Gini coefficient demonstrates how income has changed for poor and rich. If the Gini coefficient is rising as well as GDP, poverty may not be improving for the majority of the population.

<u>Module 2: Design of Energy Systems in Rural Areas</u>

This module entails a three-week introductory engineering design project on rural energy systems for developing countries. It serves as an introduction to context-responsive engineering design and is suitable for general engineering courses and introductory design courses. With appropriate modifications, it could be made appropriate to engineering analysis courses or to upper-level courses in a variety of engineering disciplines. The module highlights three characteristics of successful technology design:

1) Good design attends to **context**, including the social and natural environments;
2) Good design makes appropriate **trade-offs**, by balancing technical, environmental, social, and economic performance criteria; and

3) Good design employs **analytic tools**, both for guiding the overall design process and for making design decisions more systematically. Design analysis helps to understand context and to make better-informed trade-offs.

Module 3: Low-Cost Building Materials in Africa

This module introduces the idea of social justice in engineering, within a development context. It can be assumed that just because we are working with poor people or people in a developing country that what we are doing is right. However, we need to fully appreciate what we mean by 'right' and we need to understand the consequences of what we are doing before we might design appropriately, driven by local 'needs' and not global 'wants.' This case study provides an example of a real engineering project whose aim it is to promote social justice and sustainable livelihoods.

The socio – political context was presented in some detail in order to understand the constraints facing development and the issues of globalization of capitalism as it affects the local Basuto people. It provides an example of the questions we need to ask ourselves before embarking on any project. Who benefits and who pays? Who needs what and when? How will the project survive after the planners have gone? Who contributed to its planning and execution? Who decided what was needed? Who paid for it and why? What do they stand to gain? Are proceeds distributed equitably? Does it provide fair compensation for those affected? Are people treated ethically and justly both within and as a result of the project – workers, those affected but not involved and those who are 'users'? Who gets the jobs? Who makes decisions about pay and conditions? Do workers have to relocate? What effect does this have on their lives, their family's lives and those of their community? Is the engineering project contributing in any way to the increasing gap between the rich and the poor? How do you know? How do you find out? Do you feel you are in a position to do the right thing in your current job?

Module 4: Developing a Social Justice Index (SJI)

For decades, scholars have warned of an impending global environmental crisis. Yet politicians, particularly in the United States, have consistently shown that they are not taking the threat seriously. Initiatives aimed at protecting the planet are commonly seen as belonging to a category unto themselves-the preserve of scientists and environmental enthusiasts. Still there is little in the way of quantifying the health of the planet. One approach has recently been developed in the European Union and it is termed the Environmental Quality Index. (QOL). If engineering has only lately addressed responsibilities that we have as a profession towards the health of the Earth, even less attention has been paid to our professional responsibilities towards the poor. Somehow that notion has been seen to be outside our ethical responsibilities. A Social Justice Index (SJI) is constructed using parallel methodology.

Module 5: Numerical Methods in Bioengineering

There is growing conversation both within the U.S. and throughout the global community concerning the growing disparity between the *haves* and *have-nots* segments of the global community. Some argue that such a trend leads to a more unstable world. Others state that we have a moral obligation to help the least of our brothers and sisters. Still others maintain that the existence of poverty lies outside the responsibility of engineers and engineering. The present case study challenges students to explore their values and beliefs as well as use their analytical skills. Using data from the U.S. Government Census Bureau, various trends are examined and predictive models constructed.

Module 6: Obesity, Hunger, Energy, and Economics.

Obesity rates in the United States have been rising. In 1995, less than 20 percent of the population in each of the 50 states was obese. In 2005, only 4 states had populations in which less than 20 percent were obese, and 3 states had more than 30% obese people (Louisiana, Mississippi, and West Virginia). It is not a coincidence that in 2005 those states ranking 1st, 2nd, and 3rd in obesity ranked 50th, 49th, and 47th in personal income per capita. The highest rates of obesity in the United States are found among those with the lowest incomes. At first this may seem counterintuitive; worldwide, as countries develop economically, the population gains weight. Why is it that in the United States, the highest rates of obesity are in low income groups? This exercise explores this question further.

1. Students explore a local grocery store.
    a. Search for the cheapest item in each of the pyramid groups (grains, fruits, vegetables, milk/cheese/yogurt, meats/beans) you can find and write down each one's nutritional data from the USRDA label and cost. What is the energy cost ($/100kcal)? What is the energy density (kcal/kg)?
    b. Now find the most nutritious item you can find in each category in the store and write down their nutritional values and costs. What are their energy costs ($/100kcal) and energy densities (kcal/kg)?
2. Plan a day's menu for yourself using each of three alternative budgets:
    a. $5 (maximum individual daily allotment for a food stamp recipient)
    b. $10 (low budget/student)

Maximize nutrition regardless of cost

Module 7: Carbon Footprint

From a physics point of view, the creation of electrical current is stunningly simple – move a magnet and wire relative to each other and watch things light up. Well, maybe not quite that simple, but close. What we often skip in electromagnetism studies is how that movement is created and the associated cost. Furthermore, how do we place ourselves in the context of these costs?

In the growing concern over climate change, the various methods of electricity generation are being analyzed in terms of the amount of CO_2 emitted during production. For a fuller sense of the impact, it is also conceivable to do an entire life cycle, or "cradle to grave" analysis including other effects on the environment, how resources were originally extracted and how they will ultimately be decommissioned. This larger critique is particularly important in the case of a low-carbon technology such as nuclear power or hydroelectric power. The purpose of this exercise is for students to measure some of their own consumption of electricity and put it into the larger context of how that electricity is produced.

Final Comments

In addition to the specific course modules, we shall be developing a procedure whereby the entire process of identifying external agents (in our case, engineering organizations) and the development of course specific activities can be replicated.

At the end of the three years of the effort we shall have produced approximately 15 course modules. In addition we shall have implemented the modules in various courses and assessed how effective each has been in integrating the important issues we believe have been neglected in engineering education: the issues of war and peace; the issues of poverty and development and the issues of environmental sustainability and deterioration.

Acknowledgements

The present project is funded by through the Pennsylvania/New York Consortium grant, "Transforming Institutions through Service-Learning in the Academic Disciplines" under the auspices of Campus Compact and Learn and Serve America.

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