AC 2008-576: THE EARTH SUSTAINABILITY COURSE SERIES

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The Earth Sustainability Course Series

Abstract

A four semester Earth Sustainability-themed general education curriculum was developed by Virginia Tech in response to urgent calls for a more seamless integration of liberal and technical education. It provides a basic framework for understanding worldviews, water, energy, food, shelter, waste, and health from interdisciplinary viewpoints. Incorporating a learning community pedagogy promotes deep and meaningful learning by inviting participants to become active participants in their own learning.

The focused curriculum of many engineering programs is not in and of itself adequate preparation for meeting the needs of employers or our planet’s growing population and limited resources. But by coupling technical education with an Earth Sustainability-type general education program, and with themes carried throughout the curriculum, we can better prepare engineers to address the complex and ever-changing global problems of the twenty-first century. Engineers have great influence over the utilization of resources, so we are obligated to equip them with the cross-cultural and interdisciplinary knowledge needed to make environmentally-responsible choices. Preliminary results and findings of the Earth Sustainability program to date are very encouraging with respect to gains in epistemological development and critical thinking. The program will expand next year to include 25-30 engineers among the cohort of 150 students allowing for more detailed impact assessment.

Introduction

Undergraduate engineering programs are faced with critical challenges as they continue to adapt to address the needs of the global marketplace, and more importantly, the needs of a planet that has surpassed its carrying capacity\(^1\). Both ABET and the National Academies recognize the need for a new kind of engineer who has deep cross-cultural and cross-disciplinary competencies. In response to mounting economic pressures and competition from other countries, engineering programs have historically responded by becoming more specialized and more technical to produce students who could readily contribute to growing industries. However, this model of specialization is no longer entirely adequate for today’s complex problems that cut across the boundaries of academic departments, nations, and cultures. In addition to technical knowledge and skills, engineers today need two other fundamental competencies: (1) an ability to apply math and science tools at the intersection of global economics, culture, government, health, history, and the arts; and (2) a deep appreciation for the limits of our available resources, and the need for socially-responsible cradle-to-cradle\(^2\) designs that protect the health of people and the environment.

A recent report by the Association of American Colleges and Universities states, “\textit{those who endorse narrow learning are blind to the realities of the new global economy.}”\(^3\) They outline a broad set of vital learning outcomes and argue that these must be woven throughout every curriculum rather than regarded as a separate, or less important, educational component. Domenico Grasso\(^4\) aptly describes the troubling bifurcation of liberal and technical education and calls for a new definition of the well-educated engineer:
With the ever receding horizons of technological limits, it is easy to see how engineering curricula can become increasingly dominated by technical courses. It is time to dismiss the hegemonic notion that the best engineering education is one that exposes students to the most technical information. The social sciences and the humanities must assume parity with mathematics and the sciences in the preparation of well-educated engineers. Society can ill afford engineers with a casual exposure to social sciences and the humanities. Let us engage our students in the great debates that define our times; debates, such as the sustainable and equitable utilization of resources and global security, that, by their very nature include a fundamental understanding of technology and human nature....It is for us to complement the rigors of our technical classes with the humanistic framework within which engineering resides.

Similarly, engineering programs must embrace and weave “green” topics throughout their curricula. “The eco-friendly focus has prompted the nation's engineering schools to examine their offerings and rethink overall educational philosophies to give conservation and sustainability the high priority the public and industry now demand.” New courses, certificates, and programs in green or sustainable engineering are being added regularly. But as with the artificial division of liberal and technical education, there is a danger of creating a divide between green engineering and “other” engineering programs.

Implicit in all of this is that all students, including engineers, need to be encouraged along paths toward greater epistemological development with the goal of contextual knowing. With rapid increases in the amount and complexity of knowledge, one must learn to evaluate information in context, and come to reasoned judgment based on evidence.

This paper describes an innovative Earth Sustainability-themed general education curriculum at Virginia Tech that is designed in part to address these stated needs in higher education. The program is open to a limited number of incoming students, including engineers. It has among its goals to provide an interdisciplinary framework melding STEM areas with arts and humanities to promote cross-disciplinary competence and a respect for the ways in which different disciplines create knowledge.

Virginia Tech’s Earth Sustainability Program

The Earth Sustainability (ES) course is a two-year, STEM-saturated, interdisciplinary alternative to the traditional liberal education available to undergraduate students at Virginia Tech. It is part of a larger initiative, the Living in the 21st Century Integrative Studies (21st Century) program, to develop a radically different model for undergraduate general education that emphasizes scientific literacy and the application of STEM knowledge. The course is designed to:
1. Promote learning with understanding in both STEM and non-STEM disciplines.
2. Encourage students to transfer information and problem-solving skills to new contexts.
3. Challenge students to develop habits of mind, action and attitude that support effective and responsible citizenship.
4. Promote and support an appreciation of different perspectives and cultural mores, and genuinely value diversity.
5. Invite and empower all learners to become active partners in their own learning.

In order to create a program that addresses all of these goals, the Earth Sustainability program is based solidly in research on STEM learning. In addition, we have incorporated empirically demonstrated instructional practices to promote students’ cognitive and social development, as we subscribe to Baxter Magolda’s argument that developmental change is the essential precursor to sustained, long-term changes in thinking and learning.

During the four-semester long series, participants are introduced to how humans both create and use disciplinary knowledge and then apply it to challenging interdisciplinary problems. Through investigations of multifaceted issues, we build perspectives across many knowledge domains and work toward greater responsibility for learning about and participating in an increasingly complex world. Figure 1 schematically depicts a curricular spiral through which disciplinary perspectives and interdisciplinary topics unite to promote greater multi-disciplinary competence while also encouraging greater intellectual sophistication.

Figure 1. Incorporating the concept of a curricular spiral to showcase disciplinary perspectives
ES is designed to eliminate the artificial and commonly exclusionary disciplinary boundaries that limit student entrance into STEM fields; hold students to a higher standard than is typical of many science and math courses at Research-Intensive universities; and challenge and support students to become personally and intellectually responsible partners in their own learning.

**Participants**

Twenty-three students participated in the pilot cohort from 2004-6; 67 began the second cohort from 2006-8. Student participants hail from a broad distribution of majors including three engineers who began as part of the second cohort. The ES series will expand in 2008-10 to a total of 150 students, with a goal of including 25-30 students from each of Virginia Tech’s colleges that serve undergraduate students including engineering.

Student participants self-selected into the program. Some, but not all students, were interested in the subject matter. Others were drawn to the smaller class size, while some were motivated to fulfill the liberal education requirements with a few less credit hours. To protect the integrity of the learning community, students could not join the series once it had begun.

The course was taught by faculty and advanced graduate students from a wide variety of disciplines including geosciences, political science, engineering, biology, horticulture, English, and interdisciplinary studies. Subject-matter experts from campus, the community, and industry, were invited to present their knowledge and ways of knowing; thus, ES students had ready access to faculty who are world-renowned in their fields and represent a variety of disciplinary perspectives and ways of creating knowledge.

**Series overview**

The four-semester, four-credit course (totaling sixteen credits) met five of the seven general education requirements at the University. Only the writing and discourse and quantitative and symbolic reasoning requirements were not explicitly met, although both were integral to the course. ES met three times each week. A 75-minute period on Tuesday allowed the whole group to meet with a guest speaker or faculty lecturer. A second 75-minute class on Thursdays was devoted to discussion of the speaker and the week’s readings. A three-hour workshop on Fridays provided a block of time for field trips or activities of longer duration. On Thursdays and Fridays, students generally met in smaller communities of 20-30 students. In addition to a traditional text book that spanned all four semesters, students were asked to purchase one to two books from the popular press and to read a wide variety of current articles, book chapters, web sites, or watch videos.

The first semester (ES1) addressed *Worldviews and Water*. Topics included human relationships to nature, land aesthetics, population and consumption, hydrology, water mythologies and religion, surface water, climate, and water law, water as a commodity, and freshwater resource challenges internationally. Early in this semester, groups developed guidelines for classroom climate and participation that are essential to the formation of a functional learning community. Sessions were devoted to developing learning skills and knowledge of self and others. These workshops included team building, learning styles, critical thinking, problem solving, note-taking and time management, intentional reading, ethics, writing scientific reports, and locating and evaluating information sources (Figure 2). The group benefitted from field trips to the local
water treatment plant and to Natural Bridge, an impressive and historic geological formation with hiking trails and a replica of a Monacan Indian village. Students completed projects related to fieldwork on groundwater (Figure 2), generational changes in consumption patterns, and work with poetry and clay. Students read and discussed Water: The Fate of Our Most Precious Resource.

Energy and Shelter were the foci of ES2. Highlights from the energy portion of the second semester include: history of fuels; energy and conflict; geosciences of fossil fuels; climate change; life cycle analysis; politics of fuel; economics; nuclear power; peak oil; biomass; and renewable energy sources. Shelter topics included shelter as ecology, building materials, and history of human settlements. Semester readings were The End of Oil: On the Edge of a Perilous New World and the Art of Natural Building. Field trips included a tour of sustainably-built homes (Figure 3) that varied considerably in their design and materials, and a visit to an intentional co-housing community. A workshop on constructing dwellings (Figure 3) gave hands-on experience with structure and aesthetics. Students engaged in a significant group project to address sustainability-related issues identified by the co-housing community.
During the third semester (ES3), the themes were *Food and Agriculture* and the group read and worked with material from *Omnivore’s Dilemma*¹³ and *Holy Cows and Hog Heaven*¹⁴. By the second year, students were ready to contribute more to the learning community; they began facilitating discussions, researching and presenting current events, outlining key themes, and developing assessment questions. Students began keeping journals for personal reflection and poetry. Subjects this semester included: history of food production and farming; natural resources and farming; crop production; animal production; environmental impacts; societal and cultural aspects; sustainable farming; regulation; politics; nutrition; social perspectives; cross-cultural perspectives; ethics of eating and; the right to eat. The group compared findings from visits to two farms: a more industrialized experimental farm and a family-owned small-scale sustainable polyculture farm (Figure 4). A food science lab introduced students to the connections between yogurt production and marketing and showed how food qualities can be quantified objectively and subjectively and compared statistically. A culinary showcase and reflection on ties to the environment, culture, and personal history capped off the semester (Figure 4).

![Figure 4. Culinary showcase (L); Farm visit (R)](image)

The final semester addressed *Waste, Health, and Pathways to the Future* and culminated in group-initiated projects for Earth Day. Selected topics for class included: ecosystems, the merging of art and science, solid and hazardous waste, heavy metals, endocrine disrupters, pesticides, cancer, sustainable business models, green engineering, religious and philosophical perspectives, and global perspectives. Readings for this semester were *Living Downstream: An Ecologist Looks at Cancer and the Environment*¹⁵ and *Cross Pollinations: The Marriage of Science and Poetry*¹⁶. Class work was supplemented by trips to the local wastewater treatment plant, solid waste and recycling facility, and a nearby human-engineered lake and experiment station.

The learner-centered course design was carefully and deliberately created to enable students to engage with the material and with each other to foster broad intellectual development. The overarching goals of the course are to enable:
Gains in scientific reasoning including mastery of key STEM concepts and methods with sufficient depth to allow generalization and application to a broader range of scientific applications.

Epistemological development that provides the cognitive infrastructure for longer-term gains in scientific reasoning and correlates with more general advances in critical thinking.

Critical thinking as demonstrated by increasingly sophisticated analysis, evaluation, application and synthesis as indicated, in part, by the ability to discover patterns of information in data across fields, interpret the meaning(s) of those patterns, and argue convincingly for significance of the interpretation.

Greater engagement of students in learning.

Results

A comprehensive set of both quantitative and qualitative development measures have been assessed throughout the ES program and compared to a matched set of controls. Results for the measures of epistemological development and self authorship for the first cohort are forthcoming and striking. In a four-stage epistemological development model, students in the ES program on average showed evidence of having moved one complete stage in just two years as compared to the control group who showed almost no progression\(^7\). In general, students have been shown to shift just one-half of a developmental stage in four years of college\(^8\).

In addition to the empirical evidence that shows the ES program is meeting its intended goals, students themselves recognize the uniqueness of the ES course series. These following quotes are excerpted from an assignment at the end of ES3 in which students were asked to look back on assignments and activities and identify (1) connections they made outside of class and (2) new insights into themselves. Note that students were not asked to compare ES to other courses, yet they drew those distinctions of their own accord.

*I really enjoyed the poetry workshop. I love any activity where I can be creative. I feel that in college there are not many opportunities to think outside the box and use my right brain. The exercises show that there is more to school than objective information. A lot of things in life are subjective, interpretable, and changing.*

*I have been so used to the mundane task of basically eating and regurgitating information for every class that I can honestly say that I was at first dismissive when it came to this [journal] project. Once I finally sat myself down... I found it to be something one rarely ever experiences in a college course: a chance to channel my creative energies. It no longer was an assignment in my mind, but something I could have fun with all the while reflecting on ideas and materials that we had covered in class.*

On a weekly basis in class discussions and in their journal entries, students demonstrated the ability to make clear connections to their personal lives, to other courses, and to their community. They began viewing information from a multitude of perspectives.
Throughout this semester in Earth Sustainability, I have been able to make an assortment of connections. I feel like many students in college are trapped in this sphere of social psychology preventing them from making connections between classes and their own lives on any level. With a program like Earth Sustainability, I think we are all being slowly reprogrammed to make these connections and be glad that we are doing it.

I have learned to place meanings behind these everyday [foods] that extend beyond their physical values. These meanings often include the social, political, and especially environmental impacts that these objects may have in the world.

The power of information – both as knowledge producer and consumer – became evident to many. They developed sophistication in the way they viewed, analyzed, and acted on information.

Many of the projects we were assigned this semester required that we never accept anything as it is. An early project was the annotated bibliography. I was only a few minutes into the project when I realized how unreliable and impractical some of my sources were...I acquired an understanding that even seemingly trustworthy information could be laced with bias and half-truths. I have taken this into consideration for my daily life, always asking myself what an individual or corporation’s motivations may be.

This information can be rather overwhelming and discouraging. However, instead of accepting these faults as fate, we should use this new knowledge as motivation for change.

Other advantages of an ES-type program are far reaching. Students are engaged and responsible learners and they are assuming leadership roles on campus. Faculty participants have enhanced their knowledge of content areas outside their disciplines, have increased opportunities for interdisciplinary research, and are supported in their professional development of contemporary pedagogical methods. Senior graduate students teach alongside faculty colleagues, while undergraduate teaching assistants, who are graduates of the ES program, model the skills and attributes expected of the students. Because the course series subscribes to a learning community pedagogy, all members contribute to and are responsible for teaching and learning, and all members derive benefits.

Conclusions

The ES program goals map directly to each and every outcome goal prescribed by ABET. This holistic approach to the ABET program outcome criteria stands in stark contrast to the common approach of scattering the desired learning outcomes through a patchwork of individual courses within a curriculum. We suggest that this type of themed general education program should be considered for wider use, particularly among engineers, for whom curricula tend to be somewhat narrow. For non-engineers, this program provides a deeper look at mathematical, scientific, and
engineering concepts within the context of researching and providing potential solutions to real-world problems— including problems that are directly related to those that student participants will and are encountering.

The ES program offers one pathway for encouraging connections and linkages among STEM areas and the humanities and arts, and it shows evidence of promoting student development, critical thinking, independent learning, engagement, and action. It does, as Domenico Grasso suggests, “engage our students in the great debates that define our times; debates, such as the sustainable and equitable utilization of resources and global security.”

We need engineers who are creative, compassionate, and can think broadly about the complexities of sustainable design, development, and use so that they are equipped to mobilize the necessary shift toward more sustainable practices. We posit that it is necessary to integrate liberal with technical education AND to integrate issues of sustainability across the curriculum to effect the change called for by those who advocate that higher education must change to meet the needs of a post-industrial society.

We believe that by involving engineering students and incorporating engineering tools and methods into an interdisciplinary sustainability-based curriculum, we can encourage the development of a new breed of engineers who are sensitive to and can contribute to solving the complex interdisciplinary challenges that are the hallmark of the 21st century.

The ES series will continue in fall, 2008 with a larger role anticipated for engineering students. The assessment is ongoing and we will be looking specifically at the impact of this program on the education and development of our graduate engineers.

References