Greening the Technological Curriculum: A Model for Environmental Literacy

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The results of a national survey on environmental attitudes show that while the vast majority of Americans support environmental protection, they are not environmentally literate. Lacking basic knowledge about key environmental issues, our citizens rely on outdated, incorrect information and on common myths when making environmental decisions. When surveyed by the National Environmental Education and Training Foundation/Roper Starch (1998), Americans did not know the leading causes of water pollution, the benefits of wetlands, or the protection provided by ozone.

Is environmental literacy a responsibility of colleges and universities? If it is, then how is environmental literacy defined? What should be taught? Are the teaching strategies different for students in technological curricula? This article focuses on these questions and on developing responsible environmental behavior for students in a technological curriculum. It describes one model for environmental literacy and delineates six principles of greening the technological curriculum.

Environmental Awareness in Higher Education

Environmental education in colleges and universities is neither new nor unique. Environmental studies and sciences programs were first established in the early 1970s after the first Earth Day, a response to the growing public awareness of environmental studies and sciences issues. Almost one third of all existing environmental education programs were formed between 1970 and 1974; another third were instituted from 1990 to 1994, following Earth Day's 20th anniversary (Strauss, 1996). The number of environmental studies programs continues to rise. The 1998 edition of *Peterson's Guide to Four-Year Colleges* lists 983 programs in institutions across the country offering majors in eight environmental fields (environmental studies, environmental sciences, environmental biology, environmental engineering, environmental education, environmental health sciences, environmental engineering technology, and environmental design). These specialized programs on the environment are vital to preparing students for environmental scholarship or careers.

However, all specialized environmental programs will reach only a minority of undergraduates. Students who do not major in environmental sciences or studies or who do not elect an environmental course will miss an opportunity for developing responsible behavior toward human and nature relationships. Colleges and universities have been challenged by international mandates such as Agenda 21 and national measures such as The National Environmental Education Act of 1990 to increase their role in developing environmental literacy in all graduates. Agenda 21 (United Nations Conference on Enviroment and Development, 1992), for example, which is the blueprint for action adopted by the world's leaders at the 1992 United Nations Earth Summit, calls for colleges to implement a general environmental education program to accomplish environmental literacy through integration in courses that reach across the curriculum.

There are many promising examples of integrating environmental education into already existing courses. The liberal arts curriculum, for example, has proven a natural ground for analysis of the interdependence of earth and its living systems as demonstrated by Oberlin College in Ohio and Green Mountain College in Vermont. A rich resource for the liberal arts professor who wants to incorporate an ecological perspective into a traditional discipline may be found in *Greening the College Curriculum: A Guide to Environmental Teaching in the Liberal Arts* (Collett & Karakashian, 1996). Tufts University in Massachusetts established the Tufts Institute of the Environment to train faculty in all of its schools and colleges to link environmental literacy concepts with the practice of teaching. Northwestern University in Illinois sponsors a conference to teach business professors how and why to bring environmental issues into their classrooms. These approaches create important opportunities for nonmajors to take environmentally oriented courses; however, they do not reach the majority of college students. Environmental literacy can only be accomplished for all graduates by requiring environmental instruction in the general education curriculum.

Defining Environmental Literacy

Strictly defined, the term *literacy* has long meant the ability to read and write. Newer international and national literacy studies have changed the definition of literacy from a conditional absolute—a person was either literate

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or was not literate—to a mode of behavior. The International Adult Literacy Survey (Organization for Economic Cooperation and Development, 1995) defines literacy as using printed and written information to function in society, to achieve one's goals, and to develop one's knowledge and potential. Literacy has taken on plural characteristics, and we think of many different literacies in addition to reading and writing—technological literacy, visual literacy, or mathematical literacy, for example.

Environmental literacy is defined in both cognitive terms with knowledge as a necessary precondition of thoughtful behavior and action and in conative terms with behavioral change following directly from knowledge and skills. Environmental literacy is essentially the capacity to perceive and interpret the relative health of environmental systems and take appropriate action to maintain, restore, or improve the health of those systems. Functional environmental literacy is the capacity to use fundamental environmental knowledge, concepts, and thinking skills to formulate action positions on particular environmental issues and in daily behavior.

For example, students might be said to be environmentally literate on the issue of ozone depletion if they were able to describe the relationship between natural and social systems; define key terms; analyze the historic implications such as the Montreal Protocol in 1987 and the social and cultural aspects of these issues compared to current implications; assess the economic, political, and philosophical effects of ozone depletion; and finally, evaluate their individual behavior and its impact on ozone depletion.

A Model for Environmental Literacy

In 1992, a group of researchers at the New Jersey Institute of Technology (NJIT) began studying environmental literacy for technology students under Environmental Protection Agency funding for an Integrated Pollution Prevention Initiative. The research showed that students in science, engineering, and technology believe that technology is an important criterion in environmental problem solving and that there had been a lack of attention paid in higher education to human interactions with the environment. The goal of this project was to help sudents combine social science's emphasis on contextual analysis with humanities' emphasis on the human condition to address enviromental problems (Coppola et al., 1997). This fusion is corroborated by other technology colleges. For example, Georgia Institute of Technology's dean of engineering has said that the challenge of engineering education is to change the mind-sets, not just the problem-sets, regarding environmental issues in engineering programs (Chameau, 1999).

The NJIT strategy needed to provide for the tertiary aims of administration, pedagogy, and outcomes; therefore, core studies were developed that would provide for wise use of the General Undergraduate Requirement (GUR), for learning that involves critical thinking and cognitively complex environmental concepts, and a mechanism to capture evaluation of student learning.

The resulting curriculum change was a course required of all NJIT students—Society, Technology, and Environment (HSS 202)—which examines the relationships between the creation and use of technologies, the human and natural environment, and the development of social and cultural institutions. The course fosters an understanding and critical analysis of the political, economic, philosophical, historical, and cultural contexts of the human interaction with nature.

The project at NJIT has also followed curricular reform literature that suggests students will come to know and appreciate the traditional liberal arts subjects best if they are presented not as alternatives to their engineering and technology courses, but as related and complementary to them. Our guiding rationale is that environmental issues, such as sustainable development, cannot be analyzed solely by technological, scientific, or engineering methods. Rather, environmental awareness, like environmental practice, is also driven by social ideals, attitudes, and values.

Overall, core studies at NJIT were transformed to a more coherent program that demonstrates the connection between humanities and social sciences and the students' professional studies. For example, in the lower division of the GUR, a first-semester course was revised to include written, oral, and collaborative communication. Writing and speaking assignments are drawn from readings that relate the humanities to technology. The second lower division course, HSS 202, which fulfills the GUR in basic social science, is also geared to specific needs of technology students.

The course develops important skills that enhance the students' problem-solving abilities across disciplines as shown in Table 1. The first disciplinary topic, History and the Environment, for example, delineates a problem-solving strategy for environmental history, then applies the strategy to a case study in environ-

Table 1. **Environmental Problem-Solving Strategies**

Chapter	Strategies in Environmental Problem Solving	Case Studies
History and the Environment	1. Place the environmental problem into context of social, cultural, and environmental influences of environmental history 2. Study how humans preserve, exploit, and/or conserve the natural world 3. Assess the significance of the environmental problem	• Hetch Hetchy Valley • The Pollution Prevention Act
Communication and the Environment	1. Identify and analyze the prospective audience 2. Articulate purpose and goals 3. Arrange ideas 4. Deliver visual information 5. Collaborate on communication tasks 6. Solicit feedback 7. Incorporate change	• Pollution Prevention Team for Wallpaper Manufacturing Company
Philosophy and the Environment	1. Articulate a list of goals and motivations 2. Explain the basic values of each policy alternative 3. Test the values 4. Narrow the field of alternatives 5. Analyze further any remaining possibilites 6. Choose your position	• Motivation in Land Development • The Prisoner's Dilemma • Preservation of Species • Policy Alternatives in Pineville Forest
Literature and the Environment	1. Apply modes of analysis to literary text a. Historical b. Formalist c. Hermeneutic d. Mimetic 2. Interpret analysis to determine environmental attitude	• Ralph Waldo Emerson • Gary Snyder • Henry David Thoreau • Aldo Leopold
Economics and the Environment	1. Understand economic systems a. Custom and tradition b. Command and control c. Market system 2. Apply economic concepts to environmental issues	• NOx Emissions Reduction
Geography and the Environment	1. Describe the resource 2. Identify and describe the resource users 3. Select and prepare the tools for analysis 4. Interpret what these tools have revealed 5. Develop an action plan	• Groundwater Quality Management
Aesthetics and the Environment	1. Apply modes of critical analysis to art a. Historical b. Formal c. Semiotic d. Sylistic 2. Interpret analysis to determine environmental attitude	• Thomas Cole • Ansel Adams • Frederick Church • Othello Anderson
Political Science and the Environment	1. Collect empirical data on problem 2. Examine the historical and social conditions 3. Consider competing interests on both a local and global scale	• Motivation in Land Development • The Prisoner's Dilemma • Preservation of Species • Policy Alternatives in Pineville Forest

mental history, and finally presents a case study that asks the students to undertake their own problem-solving strategies. The steps in the problem-solving strategy for environmental history include three phases of analysis.

The first phase in the analysis of an environmental problem is to put into context the social, cultural, and environmental influences of the case at hand. Social influences on environmental history are those behaviors exhibited by a community. Cultural influences on environmental history are the ways of life by which a society operates. Environmental influences on environmental history are the variables found in natural environments of the past. The second phase for environmental historians is the study of how humans in a particular situation preserve, exploit, and/or conserve the natural world. The third phase in environmental problem solving is to assess the significance of the case at hand. How has the environmental case under analysis contributed to knowledge? How have our preconceptions been challenged? Has the case study presented the experiences of diverse groups?

The challenge for instructors and researchers in environmental education is to move students away from simplistic solutions and toward more complex approaches to viewing environmental problems. For example, if we were to ask our students to recount the history of an event, the students would probably describe the event chronologically: first one event happened and then another. To shift the students' thinking from this conventional paradigm, the environmental history dialogue begins with a brief history of shipbuilding in colonial America, chronicling the plethora of white pine in Massachusetts that provided ship masts and that led to British monopoly on New England forests. The students are then asked to look at this relatively straightforward event from the perspective of environmental history, in which chronology shifts to the background as relationships between humans and their environment take the foreground.

The colonists' use of white pine for ship masts is an excellent example of how humans interact with the environment. What was the impact on the colonial environment, for example? What were the economic policies among European nations that led to the need for shipbuilding in the first place? Through a discussion of these questions and others, students are drawn to an understanding of how environmental history helps us find new interpretations of our country's past. And by looking at this event through the lens of environmental history, we may clarify present options and learn to make our contemporary decisions in an informed way.

Living at the end of the 20th century, students are apt to overlook the inescapable fact that humans are connected with the natural world. Technology itself often enhances our vision of the natural world. The study of environmental history reminds us that we are forever bound to the earth. By looking at colonial America and its use of forests, we may better be able to understand economic drives that continue massive reforestation in the United States where increasingly forests are seen as renewable resources. Thus, we can secure our future with knowledge of errors of the past and means to provide sustainable resources.

Six Principles of Greening the Technological Curriculum

1. The curriculum should prepare students for realistic problem solving in authentic contexts.

Problem solving is intrinsic to the role of education in engineering, technology, and science. For example, the Accreditation Board for Engineering and Technology (ABET) Engineering Criteria 2000 identifies problem solving as a demonstrable goal of graduates of engineering programs. The ABET website offers full text of Engineering Criteria 2000, including: "Engineering programs must demonstrate that graduates have an ability to identify, formulate, and solve engineering problems." Jenkins (1997) noted that in our increasingly global, diverse, and technology-driven world, problem solving is critical to the accommodation of knowledge and understanding within the field of technology education. Problem solving is the heart of human technological behavior and the overriding concept of technology studies (Sinn, 1996).

Tasks are presented in authentic contexts rather than in abstraction so that students in the NJIT course understand the relevance of their work. Students are often asked to assume the role of policymaker, technician, or concerned citizen. In one case study, the student plays the role of a summer intern hired by a pharmaceutical manufacturer in New Jersey. The intern's job assignment is to investigate the Pollution Prevention Act of 1990, its origin, development as a national movement, and the legislation's impact on the plant's manufacturing process. Students read the text of the Pollution Prevention Act, perform a bibliographic search to find information about the act's origin and development, and apply

the problem-solving method explained in the class. Students are directed to look for information related to the significant social, cultural, and environmental influences that inspire and drive the principle of pollution prevention, leading to both macro models (the prevention emphasis as a national environmental orientation) and micro models (how pollution prevention work is done at corporations such as Sandoz Pharmaceuticals, Chevron, Monsanto, and Dupont).

2. The curriculum should include a human element in exploration of engineering and technology problems and solutions.

Technology students need to appraise realistically the role of human activity in contributing to the current environmental situation and the role of technology in providing solutions. Conventional approaches to higher education often emphasize linear, compartmentalized thinking and segregate humanistic viewpoints from engineering and scientific perspectives. But complex environmental issues require the intermingling of human society, natural ecosystems, and content knowledge.

Barat and Elliot (1993), for example, used an ecologically informed and holistic approach to the teaching of chemical engineering. Their work argues for an appreciation of the human enterprise, environmental awareness, and the fundamentals of chemical engineering. As they stated, "This individual [the chemical engineer] is neither a technical specialist working within a cultural and technical vacuum nor a social revolutionary who lacks technical competence" (p. 4).

One case study used in the course asks students to analyze one of the most famous examples of controversy over the use of natural resources: the fate of California's Hetch Hetchy Valley. The student who reads this chapter will become familiar with the technological solution to the problem of San Francisco's dwindling water supply. The Hetch Hetchy Valley, which is located 150 miles away from San Francisco, was targeted by engineers of San Francisco to provide a reservoir by damming the lower end of the valley.

The ensuing controversy revealed the human element in environmental problem solving. John Muir (1912), founder of the Sierra Club and one of the great naturalists of the late 19th and early 20th centuries, believed that Hetch Hetchy Valley, and all wilderness, must remain wild. At the same time, Gifford Pinchot (1910), the first chief of the U.S. Forest Service and founder of the Yale School of Forestry, advocated that Hetch Hetchy, and all natural resources, must be used for the benefit of civilization. These two men led a debate over the valley's ultimate preservation as wilderness or exploitation as a water supply system. As students review the social, cultural, and environmental influences surrounding the use of the Hetch Hetchy Valley, they come to understand the complex relationship that we Americans have had with our natural world.

3. The curriculum should be cross disciplinary.

When we analyze realistic problems faced by our technological society, environmental pollution, for example, then we realize that environmental problems themselves tend to be multifaceted. They often transcend the scope of any one discipline. Analyzing the environmental impact of a product's package design requires collaboration of several disciplines: social sciences to provide an economic assessment of the package's life cycle effect on the environment, humanities to evaluate the aesthetics and ethics of design change, and natural sciences to provide a toxicological analysis of chemicals in the packaging manufacture and disposal. Multidisciplinary collaboration has therefore become an essential element of any kind of environmental research, planning, and management. Interdisciplinary teaching sharpens students' awareness of critical connections and contradictions. Like the divisiveness that comes from framing arguments according to value dualism, confining the perspective of environmental problem solving to a singular discipline works against any effective solution.

The presentation of the core ideas is related in explicit ways to other fields represented in the course. Environmental history is explained through its connection to economics, for example. In the study of environmental history, the field of political economy has proven to be a helpful complement to analysis. By concentrating on the political economy of a nation, the environmental historian can more clearly understand the agenda of environmental policy. The case study and task are thus broadly multidisciplinary: students are asked to solve problems by looking both within and beyond a single field of knowledge and by synthesizing the knowledge base of several disciplines.

4. The curriculum should be communication intensive.

All environmental problem solving involves communication. A conversation among farmers about crop rotation, a debate among disputing parties to negotiate an acceptable reso-

lution to highway construction, a feasibility report on land use, or competing proposals at a global climate conference to reduce emission of greenhouse gases are all examples of environmental communication. Students need opportunities to build communication skills including writing, public speaking, collaborative work, and listening.

Again, ABET Criteria 2000 attempts to ensure that all engineering programs demonstrate that their graduates have the ability to communicate. To create effective environmental communication strategies, students might learn stakeholder analysis that assesses the audience's attitude, knowledge, and desired behavior (Coppola, 1997). Students in technical disciplines need particular guidance in adapting messages to a variety of intended readers or listeners.

Compelling and competent writing is required to complete the assignments at the end of each disciplinary topic. One case study requires the students to role play various members of a pollution prevention team in a wallpaper manufacturing company who are charged with discovering waste minimization opportunities. The case study presents several pollution prevention options, all with competing and sometimes conflicting demands on resources. The assignment asks students to analyze options, justify their choices, and present their findings both in an oral presentation to the firm's administrators and in a written feasibility assessment.

5. The curriculum should provide a rational approach to environmental problem solving.

Controversy over environmental issues is the result of differing value systems among stakeholders. Educators need to make clear to students that the affective domain—the attitude and belief systems of people—is important in determining how people respond to environmental issues. Whether students are role playing a corporate employee who is championing a pollution prevention program or a government worker who is helping businesses change their pollution practices, awareness of the principles of behavior change is essential to effect environmental change. Students need to learn to allow for the fact that differing personal values exist and to approach environmental problems without a crisis mentality. For teaching methods and materials that address the affective domain, educators may go to the Enviromental Education Link on the Internet (n.d.), an educational resource on the World Wide Web, supported by the North American Association for Environmental Education (NAAEE) and Environmental Education and Training Partnership (EETAP).

A crisis approach to environmental problem solving results in framing environmental arguments. Using language of divisiveness, polarity, and exclusion, framing draws lines between groups and frames arguments so people stop thinking and stop talking. Divisive language creates a simplistic dichotomy between "us" and "them," between the environmentalist who wants to protect the environment at any cost and the developmentalist who wants to preserve economic prosperity at any cost to the environment. This language, according to Killingsworth and Palmer (1992), which promotes exclusion and polarity, is called "ecospeak."

The course aims to introduce rational methods of thinking about the earth's environment. Rationalism suggests that individuals have the ability to define problems comprehensively and formulate a coherent search for solutions.

The Hetch Hetchy Valley controversy is presented with a rational approach. Students are cautioned that value dualism (nature as a source of inspiration versus nature as a fund for human development) led the Hetch Hetchy incident to become America's first national environmental controversy. Students are asked to carefully evaluate both Muir's opinion and Pinchot's view of Hetch Hetchy's outcome in order to avoid these oversimplified polarities: civilization/wilderness, utilization/aesthetics, conservation/preservation.

Rational action is the consequence of critical thinking. Therefore, the course attempts to develop the student's ability to think critically by fostering the following:

- Independent thought—the ability to move beyond simply memorizing formulae to analyzing and constructing meaning from complex data and theory.
- Intellectual breadth—the ability to move beyond disciplinary specialization to look at issues from different perspectives.
- Cultural breadth—the ability to understand differences in perspectives arising from economic status, race, gender, and class.
- Ethical awareness—the ability to understand the impact of our technical decisions on others, the environment, and ourselves.

As shown in Table 1, the course adopts a consistent format that presents core critical thinking strategies of each discipline as they are used in environmental problem solving. The application and task are also presented in situated learning contexts as case studies to promote fuller analyses.

6. The curriculum should move students from awareness to action.

According to Roth (1991), "People tend to progress along the continuum of proficiency in environmental literacy in stages that include: awareness; concern; understand; and action" (p. 44). Students should be able to demonstrate in some observable way what they have learned and their knowledge of key concepts and skills acquired.

In a discussion of groundwater management in the geography and environment modules, students analyzed resource users in a particular New Jersey area that was reporting elevated incidents of childhood cancer. The students' interest in this topic took an unusual turn when they decided to take an active involvement. Impressed by the community's ability to motivate interest from local, state, and national entities and to generate publicity for the community's fight against cancer, the students developed and published a web site so that other communities facing similar environmental pressures might benefit from the lessons learned. This exercise encouraged students to reflect on their own relationship with the environment and to imagine how this relationship might be changed.

Evaluation of a Green Curriculum Initiative

More work needs to be done in order to collect empirical and qualitative data to determine the effectiveness of our approach. However, assessment results show us every evidence that students perform well and express their critical thinking skills in writing, and that they like the course. Evaluation of HSS 202 (Society, Technology, and Environment) covers both the student's assessment of the course via traditional course evaluations and the student's performance in the course via holistic scoring of portfolios.

To evaluate the effectiveness of a course, instructor, and teaching materials, NJIT students evaluate all courses every semester. The evaluation form used by the Humanities and Social Science Department lists 18 criteria to judge effectiveness and a 5-point scale for evaluation. HSS 202 was evaluated by 128 students in the fall 1997 semester. All of the 18 criteria were rated in categories of excellence (either 5 or 4). For example, 90% of the students rated "mastery of subject matter" as excellent, while 83% evaluated "preparation for class" in the excellent categories. The "educational value" of the course was rated as excellent by 69% of the students, and "appropriateness of assignments" received an excellent rating by 79% of the respondents. The results of these course evaluations tell us that the subject matter and presentation of the material for the course engage student interest.

In conclusion, the work described in this article is not the only attempt at greening the technological curriculum. Many colleges have introduced environment-focused courses and research programs throughout the engineering disciplines. The green literacy project at NJIT does demonstrate that science, engineering, and technology do not possess the only framework of knowledge that renders an understanding of our world. The humanities and social sciences also provide excellent models for environmental problem solving. Moreover, the humanities and social sciences provide a rich, enduring framework for technical knowledge and practical application that can lead to a fuller understanding of our relationship with our world. Our students in a technological university often do believe that technology is both the driver in environmental problem solving and the solution to our planet's ability to absorb the waste we produce. We cannot say that we are creating an environmentally literate society. But as our students gain an ecological perspective, they become more creative and responsible citizens. Thus they fulfill an implicit goal of American higher education, which is to prepare students to participate in a modern world that is increasingly challenged by complex environmental issues. Certainly, a critical role for Americans is to protect both the quality of life and the quality of the environment.

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