Environmental Education Research:
Implications for Engineering Education

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ABSTRACT

Most environmental education in engineering has pertained to the
development of technical environmental engineering skills. How-
ever, at the post-secondary level, the spectrum of environmental
education approaches is broad, and no consensus exists on the ne-
cessary curricular mix for forming effective environmental profes-
sionals. This paper examines the tension between the environ-
mental education goals of knowing and caring: learning to scientifically
describe how environmental processes work, and learning to value
and feel concern for the environment. Literature on the develop-
ment of environmental sensitivity is explored for insights into how
the environmental sensitivity of engineering students could be
assessed and nurtured.

I. ENVIRONMENTAL EDUCATION RESEARCH:
A WINDOW FOR ENGINEERING EDUCATORS

"...[E]ducation is environmental education."

What if engineering students could imagine hydrology from the
perspective of fish? In 1997, we began testing enhancements to an
introductory hydrology course in the Civil Engineering Depart-
ment at the University of Toronto. The purpose of the enhance-
ments was to help engineering students understand the implica-
tions of hydrological phenomena for life forms in the watershed,
particularly for fish. We emphasized the dependence of fish on in-
tact migration paths, flood-plain breeding, and adequate base
flows. The process included cognitive learning goals, but also had
potential for affective learning by the students as they learned to
identify with the needs of fish. In student responses to carefully de-
signed exam questions, we looked for evidence that the enhance-
ments to the course had made students more aware of the life-con-
text of engineering hydrology.

The overall goal of our study was to learn more about educating
engineering students for environmentally sensitive practice. How
could we nurture positive environmental attitudes in our students?
How could we measure whether we were succeeding? Would posi-
tive environmental attitudes translate into environmentally sensitive
engineering practice? Similar questions, regarding non-engineering

II. ENVIRONMENTAL EDUCATION
IN HIGHER EDUCATION

Four types of programs of higher education preparation for envi-
ronmental professionals are identified in reference 2: an entry point
for the study of complex problems, preparation for technical special-
ists, a way to address particular environmental issues, and action-
oriented programs for change agents (see Table 1).

Underlying the diversity in these programs is the diversity of par-
adigms for the human relationship with the environment. It has
proved difficult to identify criteria for determining what curricular
content is essential to the achievement of environmental competen-
cy. No consensus exists either on what skills environmental profes-
sionals should have, or what philosophical direction they should
take:

"For example, the phrase environmental management was once
thought to embody the necessary approach to environmental prob-
lem-solving, but it is now associated by some with only mild and
perhaps inadequate reforms to reduce pollution by application of
 technological fixes,..." Meanwhile, on the supply side of the equa-
tion, are students with a range of competencies and ideologies. One
environmental educator has noted:

"Usually I teach two types of students. The first, the budding sci-
entists, ecologists, engineers, and foresters, are usually well on their
way to believing in their science. Cracking their shell of singular cer-
tainty is a first step toward a broader understanding of how they can
later fit their education into a frequently buried earlier goal of work-
ing with the natural world...The second type of students I see are the
"bleeding-heart environmentalists"...[T]hey experience the world's
wounds deeply, but they have no rationally derived basis through
which to focus that experience..." They do not need to become scien-
tists, but they do need to have a minimal ecological literacy."
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I like to think of myself as a boundary spanner—bridging the gap between “hard” science and “soft” skills. The bridge metaphor is attractive, but it probably implies more precision than I deserve (urban sprawl comes more readily to my mind). My “professional” degrees are in Civil Engineering (an undergraduate degree from the University of Utah; and a master’s and Ph.D. from Brigham Young University). I also have an undergraduate degree in English from the University of California at Berkeley, and a master’s in Instructional and Performance Technology from Boise State University. My more recent “trans-boundary” coursework is in philosophy and technical writing. I’ve been teaching soil mechanics and structural design at Boise State, since the creation of its College of Engineering in 1996. I live in Eagle, Idaho with my wife Susan and four of our five children. In my spare time I play the guitar (ES-335, mostly blues).

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*Journal of Engineering Education* 279
1. Programs within the liberal arts framework of higher education, which use environmental issues as a motivation for learning about addressing complex problems, integrating expert knowledge, and debating different values.

2. Programs designed specifically for environmental specialists and other professionals, for example, environmental health, public health, environmental law and environmental and civil engineering.

3. Programs for addressing particular environmental issues such as wildlife, biodiversity, pollution, population or sustainability.

4. Action-oriented programs for those who plan to work in communities and organizations seeking to foster pro-environment societal change.

Table 1. Types of environmental education programs in higher education.

These two imperatives in environmental education—building the foundation of scientific analysis, and cracking the shell of singular certainty—parallel the difference in paradigms underlying the various types of programs, to give the field its intrinsic tension.

For environmental educators, “knowing” and “caring” are both essential parts of environmental education. One model of the development of environmental citizenship, based on 128 studies of behavior research literature in environmental education, identifies three major types of variables: entry-level variables, ownership variables, and empowerment variables. The major entry-level variable is “environmental sensitivity.” The major ownership variables are “in-depth knowledge about issues” and “personal investment in issues and the environment.” The major empowerment variables are “knowledge of and skill in using environmental action strategies” and “focus of control (expectancy of reinforcement).”

From this model, it is concluded that when we educate for a change in behavior, we crucially need to make curricular provision for developing of environmental sensitivity, developing of in-depth understanding of issues, learning and practicing action skills, and reinforcing internal focus of control (Table 2).

III. ENVIRONMENTAL LEARNING IN ENGINEERING

Environmental education for engineering students is intended to make them better environmental citizens. The expectation of environmental citizenship is expressed in codes of ethics and professional practice guidelines of engineering associations. The role of undergraduate engineering education regarding environmental education is laid down in policies of the Accreditation Board for Education and Technology (ABET) in the United States and the Canadian Engineering Accreditation Board (CEAB) in Canada.

In the categorization of environmental programs given in reference 2, (Table 1), environment-related engineering programs were grouped with training for other specialist professions like environmental law and public health. However, engineering education has a much broader range than just environmental engineering; many engineering students are not in environmental engineering and have no intention of becoming environmental professionals. Yet their work, and the work of their communities of practice, may have a profound effect on the environment.

Recognizing this diversity, researchers doing a study on environmental education available to engineering students chose the following delineating terms:

1. Environmental education encompasses both general (life, earth, and economic) and technological education areas that are related to the environment.

2. Environmental education for engineering students encompasses a specialty subset of environmental education designed for engineering students within their disciplines (civil, chemical, electrical, or mechanical).

3. Environmental engineering encompasses engineering disciplines related to the environment, along with related biological sciences (see idealized baccalaureate-level environmental engineering program, Table 3).

The components of the second category, “environmental education for engineering students,” were explored in reference 8. Engineering students who are not in environmental engineering programs often have access to environmental education for engineers. Reference 8 surveyed 126 engineering schools in the United States to
1. teach environmentally significant ecological concepts and the environmental interrelationships that exist within and between these concepts;

2. provide carefully designed and in-depth opportunities for learners to achieve some level of environmental sensitivity that will promote a desire to behave in appropriate ways;

3. provide a curriculum that will result in an in-depth knowledge of issues;

4. provide a curriculum that will teach learners the skills of issue analysis and investigation as well as provide the time needed for the application of these skills;

5. provide a curriculum that will teach learners the citizenship skills needed for issue remediation as well as the time needed for the application of these skills; and

6. provide an instructional setting that increases learners' expectancy of reinforcement for acting in responsible ways, i.e., attempt to develop an internal focus of control in learners.

determine the extent of environmental education available to, and/or required programmatically for, these non-specialist engineering students; responses were received from 76 schools, or approximately one quarter of engineering schools in the U.S.A. The environmental education courses for engineering students at each school were categorized as being available in five distinct programs: minor, general education, core, concentration, and special interest. The first three were categorized as "formal" programs (i.e., degree related) and the last two as "advisory" programs (faculty-student related). About 76% of the schools offered some level of programming in environmental education for engineering students, most frequently special interest programs. The implication is that almost one quarter of responding engineering schools offered no environmental education for engineering students. The challenge of providing environmental education to non-environmental engineering students is explicitly framed in reference 8 from the perspective of cognitive educational objectives for student capability, competence, understanding, awareness. Reference 8 recognizes the importance of attracting student interest, and suggests the strategies of focusing on environmental impacts on professional practice, and on formal recognition of the effort (e.g., a designation on the degree document, indicating the student's participation in an environmental program.)

The presence of environmental content in engineering programs was assessed using material from one Canadian engineering school for the academic year 1988–89. The purpose of the study was to determine the extent to which students learn to incorporate an understanding of how technology affects human life, society, and the biosphere into engineering theory and design. Using a scale from zero to 4, course outlines, textbooks, readings, lecture notes, assignments, examinations, field trips and other curriculum materials were rated according to their reference to the broader context of engineering. The findings indicated that on average, the technical core courses scored between zero and one on the four-point scale. A score of zero indicated "no reference to context issues" and a score of two meant "minor reference to context issues, which remain peripheral to the thrust of the course."

A different vision for environmental education in engineering emerged from a 1991 competency study. The study surveyed practicing engineers in British Columbia, Canada, to determine what they understood by the phrase "sustainable development." The study found that the majority of engineers find their current knowledge limits potential effectiveness of their contributions to sustainable development. Among several recommendations emerging from the study was one that proposed goals for engineering education derived from the British Columbia Round Table on Environment and Economics goals of education for sustainability (Table 4). These goals, when compared to the idealized baccalaureate program in environmental engineering, place much more emphasis on an integrative understanding of environmental processes and contexts as a basis for social as well as technological facilitation of solutions. More recently, the results of a survey of 91 British engineering schools in 1998 contributed to the development of a specification for sustainable development education in engineering education. The specification, which was a product of Forum for the Future's HE21 project, is summarized in Table 5. Although less societally oriented than the vision given in reference 12, the
• A broad background in physical, biological, earth, and atmospheric science.
• A background in the fundamentals of physical, chemical, and biological processes.
• An understanding of environmental transport, transformation, and fate phenomena.
• Basic competence in environmental engineering laboratory skills.
• Some ability to apply methods of modeling and simulation to environmental systems along with some ability to assess risk and estimate cost.
• Some ability to apply knowledge to the conception, analysis, and design of solutions to real world environmental problems.
• An appreciation and understanding of ecological relationships.
• The ability to implement technology-based solutions to environmental problems through design, construction, and operation.
• Adequate skills in oral and written communication.

Table 3. Idealized baccalaureate environmental engineering program.*

specification contains much more reference to social context than would be expected in environmental engineering.

IV. ENVIRONMENTAL CARING: ATTITUDES, MEASURES, EDUCATIONAL APPROACHES

The collection above of objectives for environmental education in engineering education demonstrates that many of the objectives suggest cognitive learning outcomes that can easily be achieved by engineering students without any alteration in mindset. Scientific interpretations of environmental events are similar to scientific interpretations of events in devices or in the built environment. But the contrasting visions presented by references 12 and 13 suggest that engineering education could be designed to nurture an appreciation of the interwoven whole. The motivation for this sort of difference, reference 4 argues, is that the environment is a web of life and should therefore evoke an ethic of caring.

A. Learning about Caring

“Caring” contrasts with the engineers’ “singular certainty” mentioned in the quotation near the beginning of this paper. That certainty is of the ultimate truth and usefulness of scientific analysis coupled with efficiency values, a certainty which includes the freedom to disregard “subjective” aesthetic and moral considerations. “Caring” is an attitude, and the process of development of caring may be revealed through what we know about the assessment and alteration of attitude. A substantial part of the literature of environmental education is on the subject of attitudes toward the environment. Studies have addressed whether attitudes predict behaviors and how attitudes are changed (this section) and how attitudes are formed (next section). This division in categories has sprung from the different needs of environmental educators who are promoting a particular behavior (e.g., recycling), and those who are trying to understand environmental concern in general.

B. Research Relating Environmental Attitudes and Behaviors

In 1990, reference 14 addressed the general question of what environmental educators could learn from attitude and behavior research. That review of the literature identified five key components of an educational program promoting environmentally responsible behavioral change (Table 6), particularly recognizing the importance of understanding learners' freedom of moral choice, and the value of respected role models. Reference 14 concludes:

“Ultimately, people need to be able to make their own moral decisions about environmental matters. The job of educators is to ensure that everyone has all the tools necessary to make responsible environmental decisions.”15
The goals of engineering education should be to ensure that engineers:

- understand the systemic nature of the world and the interconnectedness of natural and human systems;
- understand the global nature of the world and how local and regional issues are part of the whole;
- understand a variety of perspectives and recognize that perspectives and worldviews reflect values and beliefs that may not be universally shared;
- have the skills necessary for constructive participation in local, national and global communities;
- be prepared to take responsibility as contributing professionals and global citizens;
- have knowledge and skills to apply engineering knowledge in ways which fulfill their professional responsibilities and are consistent with their broader understandings (as above);
- have specialized expertise in a particular engineering discipline area.

Table 4. Contrasting vision for environmental education in engineering education.\(^\text{17}\)

Reference 16, reviewing attitude research, notes that "[a]lthough logically one might conclude that generalized concern for the environment would be predictive of a broad array of conservation behaviors, the empirical findings are equivocal."\(^7\) However, it goes on to trace the successful use of one specific environmental attitude measurement instrument in predicting environmental concern. The instrument, the New Environmental Paradigm (NEP) developed by reference 18, measures several attitudes which taken together indicate the worldview held by the respondent: a higher score shows that the respondent believes that humans should adapt to the changing limits dictated by the environment. The instrument has been validated through use with a range of research samples. Originally it was expected to measure the one dimension of ecological worldview, but it has been shown to distinguish three dimensions identified as Balance of Nature, Limits to Growth, and Humanity over Nature.\(^\text{19}\)

The NEP has been shown to be useful as an indicator of willingness to make personal behavior changes and has been compared to students’ willingness to accept tradeoffs related to environmental protection.\(^\text{20}\) In general, reference 20 found that students whose NEP profile revealed that they had a belief in limited resources and less faith in technological solutions showed greatest willingness to make sacrifices in personal consumptive behaviors.

Another strand in environmental attitude measurement research includes the work of reference 21, who designed a 100-item Likert scale instrument to assess seven dimensions of environmental concern. Later a similar but simplified study was performed.\(^\text{22}\) Both instruments were developed with industrialized countries in mind, but were followed up\(^\text{23}\) with an instrument tested on university students in Turkey, a developing country.

C. Can Environmental Attitudes Predict Engineering Practice?

An attitude measurement instrument might be useful in finding out more about the profile of a class of engineering students. For example, in a recent survey of students in a variety of educational institutions in Finland, engineers students' environmental attitudes were among the most negative, and they had, on average, fewer nature-related hobbies than students in general.\(^\text{24}\)

Could this sort of information be used to predict whether the students' engineering practice will be environmentally sensitive? To predict behavior, researchers recommend that an instrument needs to be geared to the same level of specificity as the behavior (reference 25, quoted in reference 16). That is to say, a general instrument like the NEP might predict whether people consider themselves environmentally aware, but a more specific measurement might be required if the purpose was to predict whether a person would participate in, for example, a curbside recycling program. In assessing the attitudes of engineering students, we would be seeking broad information about their world view, but we would also want information about a complex of particular behaviors which they may need to engage in to do environmentally sensitive engineering.
practice. The environmental guidelines for professional engineers in our province contain 53 items. These items express expectations placed upon engineers which range from highly concrete actions like promoting "the wise use of resources through waste minimization, reuse, and recycling wherever possible" (Guideline 4.5) to much more abstract goals like recognizing "that humanity is dependent on the ecosystem of this planet and that the environment has a finite assimilative capacity" (Guideline 4.8). An instrument designed to predict, on the basis of attitude self-report, engineers' compliance with the guidelines, would be long and cumbersome.

D. Do University Courses Alter Environmental Attitudes?

It would be helpful to the engineering educator to know more about the development of environmental values in university students, that is, the changes occurring in university students during their university years. Several studies on this subject exist, but none have focused on engineering students. Investigating changes over time in the university population, a longitudinal study compared environmental attitudes between university students in 1971 and 1981. Investigating changes in individuals, reference 28 followed eighteen thousand students from the freshman class of 1985 past graduation in 1989. The study assessed the influence of three factors (student background characteristics, institutional characteristics, and college experience) on the development of environmental attitudes; the attitudes were discerned from the students' self-report of the personal importance they attached to becoming involved in programs to clean up the environment. The findings were that being male, being liberal, and taking science courses all play a positive role in the development of environmental attitudes.

A study of a shorter-term attitudinal change taking place over the duration of one environmental studies course particularly addressed the development of an "internal locus of control for reinforcement." This psychological construct describes the extent to which individuals perceive that they have control over something, in this case, over environmental problems through the discipline of environmentally responsible behaviors. The subjects of the study were enrolled in an environmental studies course for non-majors in which "every lecture had the goal of fostering a sense of empowerment in the student to help solve current environmental problems, to prevent other problems, and to develop an ecologically sustainable lifestyle." The results indicated that over the duration of the course the subjects showed an increase in internal locus of control for reinforcement for environmentally responsible behavior, and an increase in self-reported environmentally responsible behaviors.
the program must be appropriate for the level of knowledge, attitude and moral development of the individual;

- a central component must be information about how ecosystems naturally function and about the problems that are threatening the well-being of all life;

- coupled with this should be information about action strategies, which may be best transmitted through the use of a respected role model;

- information provided should
  - explain both sides of environmental issues
  - encourage people toward direct contact with the natural environment
  - stimulate a sense of responsibility and personal control

- learners should not be merely persuaded or manipulated; rather, they should be given the skills to make future decisions for themselves.

Table 6. Components of program educating for environmentally responsible behavior.

whereas a control group who took a history course showed no increase.

A thorough study was undertaken to learn about the effects on the worldview of students taking an introductory environmental history class. The class instructors made no attempt to influence students toward any particular worldview, and provided information about both "pro-environment" and "anti-environment" perspectives. The researchers used complementary quantitative and qualitative approaches (surveys and interviews) to assess whether the students had learned more about the complexity of environmental issues in the past and the present, had become better able to articulate their views, and had shifted along the utilitarian-preservationist continuum.

V. ENVIRONMENTAL SENSITIVITY: DEEP ROOTS OF CARING

In environmental education research, the concept of "caring" has been comprehended in the phrase "environmental sensitivity," which has been used to mean "a set of affective attributes which result in an individual viewing the environment from an empathetic perspective." Empathy can be defined as the "identification with or vicarious experiencing of the feelings, thoughts, or attitudes of another." Reviewing research on environmental sensitivity, reference 32 explains the ambiguities of the phrase "environmental sensitivity" and suggests that, given the way the phrase is used in the literature, a general definition might be "a predisposition to take an interest in learning about the environment, feeling concern for it, and acting to conserve it, on the basis of formative experiences.""A. The Beginnings of Environmental Sensitivity

The review in reference 32 of research on the development of environmental sensitivity from early childhood experiences traces the literature since 1980. Reference 35 read biographies or autobiographies of conservationists, in which he found many accounts of childhood time spent in near-pristine environments. He then surveyed staff and officers at conservation organizations and learned that interaction with natural areas and frequent contact with habitats, often occurring in childhood or adolescence, were the leading influences recognized by the individuals. Reference 36 describes a similar study but instead of focusing on the antecedents of action as in reference 35 (asking participants what led them to choose conservation work), an attempt was made to explore attitude, sensitivity, interest and dedication. In 1993, reference 37 reported the results of a study of members of the National Environmental Education Association of the United Kingdom. Participants were asked both about early influences and to indicate environmental activities in which they regularly engaged. The interpretation in reference 32 of the results in reference 37 is that school and university courses,
followed by non-childhood outdoor experiences and then by childhood outdoor experiences, were the most important influences reported in reference 37.

Other smaller studies have used interviews instead of questionnaires for gathering information. In reference 38, volunteer marine biology class students were interviewed, and the data indicates that 88% of them mentioned childhood experiences of natural areas as an important influence. Reference 39 studied a more diverse group of fifty American environmental educators from various ethnic backgrounds and learned that outdoors experiences and the influence of mentors (often family members) had been important; another influence had been job opportunity in the field. Reference 40 extended the research to El Salvadoran environmental professionals, who identified the most important influence as outdoor experiences and the next most important as witnessing environmental destruction.

A limitation on all the research on environmental sensitivity described thus far was that there was no comparison with the influences on people who did not go on to become environmentalists. Some comparative studies have been done which focused on environmental sensitivity as a characteristic; the level of the respondent’s sensitivity was discerned through their responses to a questionnaire. One such study was reference 41, which gives a comparison of the attitudes and backgrounds of college seniors in environmental studies, engineering, and business. The engineering students were more likely than the business students, but less likely than the environmental studies students, to report that they enjoyed natural areas for solitary play as children and that they chose hiking or camping as recreation in college.

Speculation surrounds the actual role of early childhood nature experiences. It appears that young children “animate the world and perceive places and things to be alive and conscious.” This relationship may be the first step toward environmentalism. Alternatively, the events and exposures in a person’s life may be less important than how they construct those events (references 44 and 45).

When environmentally sensitive engineering practice is a goal, the most obvious approaches are either to recruit students who are already environmentally sensitive, or to design educational processes to transform existing attitudes in students. The existing research on the development of environmental sensitivity is of interest to the environmental educator of engineering students, but further research would be helpful, particularly in two areas: the development of negative attitudes (sources of indifference, fear and destructive toward the environment) and the effectiveness of post-secondary influences in helping students remediate earlier negative constructions of their environmental experience.

VI. IS CARING A PART OF ENGINEERING?

Environmental learning in higher education, this paper shows, takes many different forms, from learning about “knowing” to learning about “caring,” to meet the many different expectations held by students and prospective employers. Engineering has focused on the “knowing” end of the spectrum of environmental education because that aspect has been perceived as the preserve and niche of technological education. But faced with a goal of environmentally sensitive practice for engineers, the “caring” aspects of environmental learning seem of increasing importance. Following reference 4, the “shell of singular certainty”—a “knowing” problem—has been identified as a possible barrier to environmentally sensitive practice.

The literature about “caring” emerging from the field of environmental education suggests some approaches which engineering educators could use to gain insight into our students’ environmental attitudes. “Environmental sensitivity” is identified as an important prerequisite for environmentally responsible behavior. But the development of environmental sensitivity appears to occur well before post-secondary education, the window of opportunity for engineering educators. If environmental sensitivity is recognized as a necessity for engineering practice, we need to include it as a criterion in recruitment processes, or we need to learn more about what we can do to nurture environmental sensitivity in the university age group.

This paper was motivated by our desire to know more about environmental attitudes and about the efficacy of teaching students to identify with the needs of fish. We tested the learning outcomes of our fish-enhanced curriculum, compared with the original curriculum, but found the difference to be insignificant at the low level of intervention which we had chosen. Nonetheless, the novelty of the approach attracted attention from the hydraulic engineering community; it also stimulated our own reflections on the meaning of engineering. A question that remains unanswered is, who decides what constitutes environmental competency? Some would argue that engineers can be environmentally competent without developing an ethic of caring, since professionals with other backgrounds can bring that dimension to the multi-disciplinary treatment of environmental problems. By contrast, this paper proposes that caring is currently a missing component of what could be a more holistic engineering curriculum. From this perspective, learning to think like a fish is a logical first step in making informed engineering decisions that could influence aquatic environments.

REFERENCES

12. Ref. 11, Chapter 5, Recommendation 7.
17. Ref. 16, p. 1581.
30. Ref. 29, p. 32.
33. Ref. 32.
34. Ref. 32, p. 19.
43. Ref. 32, p. 18.