Fishing for a New Way to Teach Environmentally Sensitive Engineering Practice

Rosamund A. Hyde
Bryan W. Karney
Christopher A. Kennedy
University of Toronto

Professional engineers are under increasing pressure to practice in an environmentally sensitive way. To prepare engineers for this new reality, changes in engineering education are needed. For example, engineering hydrology has traditionally been taught with an emphasis on the interpretation of numerical data about rainfall and runoff in watersheds. However, to do environmentally sensitive hydrology work, it is necessary to also understand the life forms that share the watershed. In 1997, a project was undertaken in the Department of Civil Engineering at the University of Toronto to enhance an introductory hydrology course by adding information about how hydrological phenomena affect fish. Through carefully structured assignments and exam questions, an assessment was made of the effectiveness of the enhancements in increasing students' awareness of the life context of hydrology. The project has resulted in a commitment to increased environmental information in the hydrology curriculum, and the implementation of an assessment process for all students, to monitor changes in their environmental knowledge and attitudes. It has also raised questions about ultimate objectives in engineering education.

What changes might occur in a hydrology course and in a civil engineering department if engineering educators tried to devise and test a way of teaching engineering students to empathize with fish? This article reflects on an ongoing process of curriculum development that started in 1997 in the Department of Civil Engineering of the University of Toronto. The purpose of the enhancements was to help engineering students understand the implications of watershed decisions for life forms in the watershed and particularly for fish (see Figure 1). The first section of this article explains the need for environmental education in engineering education and sketches the conceptual foundations of the curriculum development project. The second section outlines the development and testing of the fish-friendly curriculum. The third section describes some of the project's effects on the department. The fourth and last section comments on the ethics of teaching attitudes and the chances of empathy-oriented teaching becoming widely accepted in engineering schools.

Inquiring Into Environmental Education in Engineering Education

Engineering and the Environment

In Canada, there are about 150,000 registered professional engineers. The four major disciplines are civil engineering (26%), mechanical engineering (24.5%), electrical engineering (16.9%), and chemical engineering (10.6%). Almost half of registered engineers (48%) work for organizations with more than

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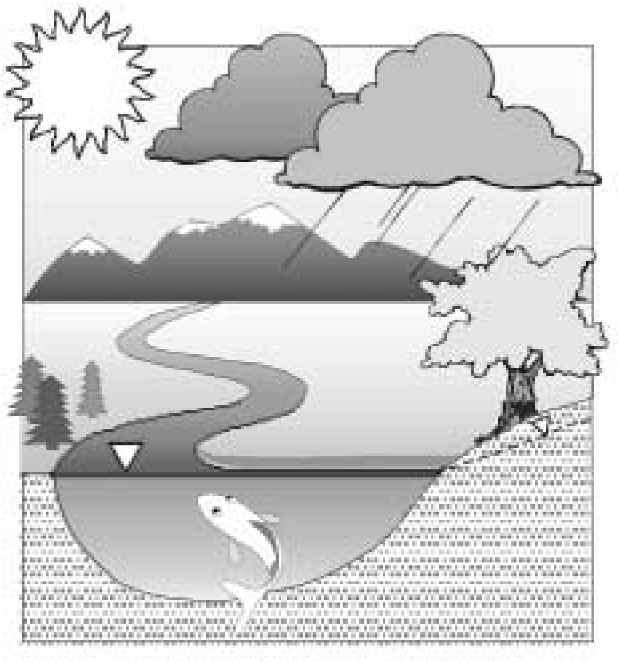

Figure 1. A Fish-Eye View of a Hydrologic System

500 employees, and a further 22% work for firms that employ between 51 and 500 people (Canadian Council of Professional Engineers, 1998b). The majority of engineers receive their undergraduate training through Canada's 34 engineering schools, which graduate about 6,000 engineering students every year. The graduates then enter a period of 2 to 4 years as "engineers in training," working under the supervision of a registered professional engineer before they are eligible for registration with their provincial or territorial professional engineering association. About 8% of the profession is currently composed of engineers in training (Canadian Council of Professional Engineers, 1998b).

The professional associations are empowered by statute to regulate the profession in each province or territory. They control entry to the profession, develop guidelines for practice, and determine discipline in the case of complaints. The profession is also shaped by engineering societies for some disciplines, associations for various sectors such as consulting engineers, and organizations at the global level. It is estimated that, worldwide, there are 8 to 10 million engineers (Thom, 1998).

Engineering work can influence the environment directly by altering or destroying natural features and indirectly through the release of pollutants and the dissemination of polluting products. Civil engineering work involves the disruption of habitat by building roads, railroads, canals, and airports, as well as the alteration of hydrological systems by building dams and urbanizing watersheds. Mechanical engineering affects the environment through the production of automobiles and other manufactured commodities. These products require the extraction of raw materials, energy for the fabrication phase, energy and other inputs while the product is in use, and eventually, disposal or reincarnation. Electrical engineering, which includes energy applications and communications applications, affects the environment through the disruption and waste involved in generation, transmission, and use of electrical energy, and through the by-products of telecommunications operations. Chemical engineering, which includes synthesis of desirable chemical products and breakdown or neutralization of undesirable products, affects the environment through its requirements for resources and the waste it generates, as well as through the environmentally damaging activities that it makes possible.

On one hand, it may seem unfair to "blame" engineers for environmental damage caused by their work when, in general, they are acting in response to problem definitions that are formulated by others (Johnston, 1997). It may even seem pointless, in that case, to attempt to change the world by changing how engineers are educated. On the other hand, people working for change in engineering education usually make the assumption that engineers in practice have sufficient design flexibility that we can, by increasing environmental content in engineering education, make engineering practice more environmentally sensitive.

The goal of environmentally sensitive practice is strongly supported by professional engineering associations. The environmental guidelines of Professional Engineers Ontario (1998) set out detailed expectations that may be summarized as saying that engineers should act as environmental advocates. The Environmental Code for Engineers developed by the Association of Consulting Engineers of Canada states that part of an engineer's role is "encouraging and promoting appropriate environmental laws and regulations" (quoted in Hibler & Beamish, 1998, p. 103). For engineering educators, recognizing that students begin practice immediately after graduation, the question is whether those graduates will be adequately prepared to meet the professional associations' high expectations.

Environmental and Engineering Education: Conceptual Foundations

Are engineers educated as if the world mattered? In one sense, engineers are educated completely as if the world mattered. Their program is totally occupied with courses that teach them to understand mathematical and physical laws, characterize physical systems, model physical processes, and realistically and practically predict the outcome of physical interactions. In this sense, an engineer's education is quite different from, say, a mathematician's or computer scientist's. Engineers are very aware of the world as a source of raw materials and space as well as a sink for waste products and spent goods.

But a bigger question is whether engineers routinely attribute to the world an intrinsic value above its use in human activity. Realistically, the program's perspective on the world is essentially exploitative and resource oriented. Engineers are primarily conscious of the world through knowledge of its constraints. Engineering education locates openness and opportunity in the agency of technology, not in the fundamental wonder and mystery of existence. Engineers often embrace aphorisms such as "the best way to control the future is to invent it" without questioning whether controlling the future is a worthy goal.

Millennia ago, engineering was used in Judeo-Christian scripture as a symbol of the human attempt to exclude God the creator from God's creation. As Jacques Ellul puts it in *The Meaning of the City* (1970), humans sought to "make a name for themselves" (p. 15) by building a city.

> How important a name was for an Israelite was well known. It is the sign of dominion and has a spiritual quality. God gave a name to the first man. Man in turn named all the animals. Thus a relationship is established in which the one named becomes the object of the one naming. . . . It was in [the city], man's environment, built for man by man, with any other intervention or power excluded, that man could make a name for himself. (pp. 15-16)

God's response in the myth was to confuse their language to make it impossible for the builders to understand each other. The message of the myth is that naming ourselves is turning away and separating ourselves from God. Separating ourselves from God means death, and by sending confusion, God calls us away from death. Instead of developing a city, a truth, a human understanding that is independent of God, we cease to be able to understand each other. This confusion is familiar to engineers and to educators; it characterizes the modern university.

The alternative, a turning toward God, is explored by George Grant (1986), who starts from Simone Weil's statement that "faith is the experience that the intelligence is enlightened by love" (p. 38). Grant defines love as "consent to the fact that there is authentic otherness" (p. 38). If we deny the reality of otherness, we see our own needs as the only needs and everything around us as resources to meet our needs. But "anything apprehended as resource cannot be apprehended as beautiful" (p. 51). If we wish to perceive beauty, we have to consent to the reality of otherness. To the extent that we perceive beauty, our intelligence is enlightened by love, and in this new sense, the world matters to us.

Although seldom debated or discussed within the engineering community, these two senses of the world "mattering" were the conceptual foundation of our exploration in environmental education in engineering education. We started by looking at the existing curriculum standard. The content of undergraduate engineering programs in Canada is determined by the Canadian Engineering Accreditation Board (CEAB), which is a committee of the Canadian Council of Professional Engineers, the umbrella organization for the provincial and territorial professional engineering associations. The CEAB's policy (1998) specifies that "appropriate exposure to . . . concepts of sustainable development and environmental stewardship must be an integral component of the engineering curriculum" (Canadian Council of Professional Engineers, 1998a). In a list of engineering science subjects given in the policy, environmental studies is included. In a list of constraints on engineering design decisions, environmental factors are mentioned.

Today, in the year 2000, we have a range of tools available to us for assessing whether this content policy is translated in our engineering programs into "education as if the world mattered." For example, at the policy level, a specification for sustainable engineering education has been developed through consultation between environmentalists and engineering educators in the United Kingdom (Forum for the Future, 1999). At the delivery level, a list of guidelines for excellence for environmental education materials has been provided by the North American Association for Environmental Education (1996).

But in 1995, when we were planning a doctoral research project to learn more about educating engineers for environmentally sensitive practice, we had to rely on our own perceptions of what important components were present and absent in our undergraduate courses. Looking at the expectations of environmentally sensitive engineering practice, we observed that both cognitive and affective learning goals were involved in preparing an engineering graduate who was willing and able to be an environmental advocate. Furthermore, we asked ourselves the question, Would an environmental advocate entering our program be nurtured or alienated?

Similar curriculum-content questions have been raised for several decades in environmental education for nonengineers. There is still no consensus either on what skills environmental professionals should have or what philosophical direction they should take (Lemons, 1994). A bifurcation exists between *knowing* about the environment and *caring* about the environment. It has been argued that knowing, especially knowledge based in scientific interpretations of phenomena, is not sufficient for an environmental professional, who needs to go further and develop an "ethic of caring" (Booth, 1998). In research on the effectiveness of environmental education, the sort of behavior pattern that demonstrates environmental caring has been called *environmental citizenship*. Two major variables in the development of environmental citizenship behavior are shown by research to be "environmental sensitivity" and "in-depth knowledge about issues" (Hungerford & Volk, 1990).

We began to lean toward the affective aspects of education, especially trying to find ways to encourage engineering students to "consent to the reality of otherness." We decided to test types of curriculum enhancement that would increase engineering students' in-depth knowledge of environmental issues without limiting their response to one of knowledge acquisition. We looked for ways to present accurate environmental information while giving students an opportunity to empathize with affected life forms. Although many design parameters in environmental engineering (for example, temperature and chemical characteristics of effluent) are determined by the needs of aquatic life forms, it was rare that these creatures were explicitly mentioned in environmental engineering courses. We chose to take one course and, without changing the concepts presented, highlight the connections between the engineering concepts and the requirements of the life forms with which we share habitat, requirements that were distinctly "other" than our own. We called this highlighting *ecological enhancement*, and our goal was to do it in such a way that the educational outcomes could be tested and compared with those of the original course.

To present our curriculum experiment as the difference between turning away from or toward God is probably the most radical way it could be described, and certainly, we did not explicitly frame it this way in the planning stages. Nor did we say these words to each other. However, as the project proceeded, we began to recognize that if we were to continue on the "ecological enhancement" path, we would be instigating fundamental change in engineering education. Even trying to understand the effectiveness of the small changes that we tested was difficult, in part because of the new goals implied by the enhancement process. Traditionally, the best engineer was the one who most comprehensively exploited (put to human use) the surroundings, and engineering students were evaluated on that basis. The enhancement process validated the goal of seeing beauty rather than resources. In the engineering school, we do not have precedents for evaluating in what ways students see beauty.

Developing and Testing an Ecologically Enhanced Course

The course that we chose to enhance was a 6-week introduction to engineering hydrology. Hydrology pertains to the movement of water through, across, and above the earth. Engineering hydrology specifically focuses on aspects of water movement that may affect, or be affected by, engineering activity. Engineering students are taught engineering hydrology so that they can understand and predict the interaction of water flows and human activities.

Unlike many other engineering subjects, hydrology is not used solely to describe behavior within a human-made system. It can also be applied to pristine natural systems. Most hydrological analysis deals with systems that are at least partly "wild." The lakes, streams, and rivers that drain precipitation are in fact the only place where freshwater fish can live. But in the past, engineering hydrology has typically been taught and studied without reference, or with only glancing reference, to life forms like fish. For example, a survey of 17 hydrology and hydraulics textbooks published before 1996 found a total of only six mentions of the word *fish* (Hyde, 1999, p. 84).

But fish are strongly affected by human interventions in hydrology. For example, fish require certain minimum flows to be able to live and breed in waterways: When those waterways are downstream from reservoir control dams, the water released from the dam needs at all times to be sufficient to meet fish requirements. The total amount of water removed from the reservoir and piped elsewhere must also be limited according to the needs of the fish downstream. Fish migration needs to be considered when hydrological regimes are altered: Urbanization can cause faster runoff from watersheds and make it difficult for fish to swim upstream. Fish breeding is a concern when rivers are prevented from flooding: Humans see floods as a risk, but for fish, floods are an opportunity to reach the warm shallow waters of the flood plain and there spawn.

Fish seemed like an accessible life form for humans to identify with. For commercial and recreational reasons, humans have a long history of observing fish behavior and preferences. Fish are somewhat similar to humans because they reproduce sexually and can in some cases live more than a human life span. That humans empathize with fish to some extent is demonstrated by centuries of building fishways to help fish struggling to ascend waterways. Further indication of the value placed on fish is that they have been the subject of works of art and literature.

Fish are good ecosystem indicators. They are sensitive to a wide range of environmental conditions, including the velocity, temperature, pH, turbidity, and chemical concentrations, and even the smell of the water they live in. They are also influenced by light and darkness, local populations of plants and animals, noise, water level fluctuations, and electrical discharges. They respond to unfavorable transformations in their environment by displaying distress, becoming lost, losing reproductive capacity, being displaced from a habitat, or dying.

Our challenge was to develop curriculum enhancements that would help students understand the experience of fish in the context of engineering hydrology. We tried two different course enhancements. For the first enhancement, we looked at the 34 solved study problems that were the illustration of the course theory and the basis for tests and exams. We took four of these problems and turned them into "fish problems." We enhanced them to quantitatively demonstrate the fish concerns mentioned in the previous paragraph: minimum flows, withdrawals, migration paths, and breeding opportunities. Because these problems evoked both cognitive and affective responses, we called them *empathetic analysis*.

For the second enhancement, we let go of the analysis aspect and tried a different empathy-oriented learning strategy: the use of narrative. We included a set of readings in the course, one of which was a group of four "fish stories." Written in the second person, the stories invite students to imagine that they are fish in a variety of degraded environments. For example, one story, based on a real situation (Brown, 1982), was about the impact of golf course development on aquatic environment:

> Imagine you are . . . a brown trout, living in a mountain stream. You are about 35 cm long, weighing less than a kilogram, with dark brown spots on your golden brown sides. You like to pass your days in cool, fast-flowing waters, and your nights catching insects at the surface, and small fish.
>
> Two years ago, this stream was a peaceful home which you shared with many rainbow trout and brook trout, each fish having its place, according to size, in the sequence of domination. One day, without warning, a great change came to the stream. The water filled with huge noises worse than the loudest crashing of rocks in a spate. Mud and broken plants surged down the stream. You tried to hide behind a large rock, but you could see nothing and could hardly breathe in the turbid water, so you let yourself be washed downstream to a quieter place. When you returned upstream a few days later, your reach of the stream was unrecognizable. Gone were the rocky bends and sheltered pools under overhanging trees. The rubble bottom of the stream had been scraped clear, and the whole stretch had been made straight. There was nowhere to hide, nowhere to spawn.
>
> Worse yet, as you swam further upstream, you found a wall across the stream with water falling down it. You wanted to go upstream to seek undisturbed reaches, but the wall was too high to jump.

> Each day, the sun shone longer and higher. With the sheltering trees gone, the water in the stream got hotter than you had ever experienced. Also, the water coming down the wall was far too hot for comfort. When there was heavy rain, the sun-warmed pool upstream would spill over down the wall, heating up the whole reach.
>
> Autumn came, but there was nowhere to spawn; the stream bottom was weedy and muddy. Only the brook trout were willing to breed there. The stream was also shallower than before. As winter closed in, the remaining water went from too hot to too cold. A thick layer of ice formed.
>
> In the spring, the rainbow trout arrived on their spawning migration, but there were no gravel beds for the females to make nests in. Also, there was something wrong with the water. It had an unpleasant taste. Crayfish and minnows seemed scarce, and it was harder to find mayflies. Unable to spawn, the rainbow trout slipped back downstream. The brook trout fry were having a difficult time. After a long incubation period due to the cold winter water conditions, they lived off their yolksacs for several months. But when they had to find their own food, they had trouble coping with the strong current in the straightened watercourse. Gradually, they too disappeared downstream.
>
> So, this spring, everything is different for the fish in this stream reach. Other brown trout, which were mature at the time of the disturbance, are still surviving in the altered system. But you can see only a few, scrawny brook trout, and you never see rainbow trout anymore. Normally every year you would notice the growth of the fish which had hatched that year. This year, there are no young-of-the-year, no sense of a future for the community.

An effort was made to find a balance between telling the story on the basis of what the fish would observe and interjecting information that the human reader could understand about the source of the environmental problems. The stories were introduced by a brief invitation to imagine being a fish, sketching the customary activities and sensory faculties of the fish for the benefit of a reader who might not know how sensitive and perceptive fish are. In the other three stories, a 70-year-old lake sturgeon swims upstream to spawn only to find that its spawning beds have been disturbed by bridge building; a sock-eye salmon struggles to ascend a river altered by dams and logging; a mottled sculpin enjoys an increasingly easy life as urban watershed restoration improves conditions in its habitat.

Developing these enhancements was relatively easy. It was more difficult to test their effectiveness in making the students more willing and able to practice environmentally sensitive engineering. A longitudinal study on transition to practice was well beyond the scope of the project. Because we had no baseline data about students' environmental attitudes on their entry to the program or the course, we could not test to see if the students' attitudes had improved during the course. We decided to try to test whether the enhancements were successful in nurturing life-context awareness in the students by comparing two sessions of the course.

First, we tested the curriculum enhanced with fish problems. For two successive years, we designed final-exam questions for the course that would give students an opportunity to demonstrate their contextual awareness. The first of these exams acted as a baseline because it was used for students who had followed the original curriculum. The second was used for the students who had followed the curriculum that included the enhanced study problems. There was no discernible difference between the two groups.

The students' responses to the fish stories was analyzed differently: They were used to learn more about students' environmental attitudes without seeking to discern a change in the students. All 120 students in the class had read the fish stories. Eleven students chose to write a short paper in response to questions about the fish stories (other students chose other readings), and the 11 papers were analyzed. The papers showed that the students' understanding of environmental issues and environmental politics ranged from good to poor.

Although the experimental design and the clarity of results left much to be desired, reports of the research project met with an interested reception at the Canadian Conference on Engineering Education (Hyde, Karney, & Kennedy, 1998) and the *Journal of Hydraulic Engineering* (Hyde & Karney, 1999).

Did the Experiment Make a Difference in the Department?

Each of us had our own vantage point for observing the effects of having an engineering graduate student doing education research and curriculum development in the Department of Civil Engineering.

The Student's Observations: Comments by Rosamund Hyde

Our project was a novelty in the department, and in fact, we are not aware of any other situations in which engineering graduate students are doing educational research focusing on affective learning. Engaging in the project brought some awareness to the authors and the doctoral committee of the difficulty of educational research and the ways in which it differs from traditional engineering research. From time to time, to assert the legitimacy of our inquiry, we have characterized engineering education as being an engineering design process like any other. However, this metaphor is flawed. From a spiritual point of view, humans are not raw materials (resources!). From a design point of view, humans are acted on simultaneously by too many unknown shaping forces to be readily understandable as a material. From a pragmatic point of view, humans are difficult to monitor in a satisfactory way to gain insight into their responses to educational approaches. It is both frustrating and intriguing that profound changes may take years to manifest themselves.

So, although we were stimulated by the variety of approaches and contacts that enriched this project, we also had a growing awareness of the challenges that we were taking on. In our perplexity, we reached out and ended up getting to know people with whom we hope to collaborate in future. We feel more connected to other scholars working on similar projects. If another graduate student started an inquiry into engineering education, we would know where to find guidance for developing a coursework program that would serve the student well in their research.

One effect of having an engineering graduate student doing educational research was that it led to opportunities for the discussion of educational issues. One concrete example was that during a meeting of the doctoral committee supervising this project, a committee member mentioned that he had done a pretest of his applied ecology students. His willingness to share the information from the pretest gave us access to another perspective on the engineering students' backgrounds. Our willingness to analyze the pretests in detail brought them to the attention of other members of the department. A lasting effect has been the development and administration of the first round of a pre- and posttest to understand the environmental knowledge of students in the Collaborative Environmental Engineering Program.

One follow-up to the empathy-oriented learning project was a survey developed by Chris Kennedy and myself (Hyde & Kennedy, 2000). The survey, which inquired into how engineering educators assess the development of environmental attitudes, was distributed to 100 engineering educators involved in teaching about the environment. The response rate was 24%, and only 2% of those surveyed reported that they assessed environmental attitudes.

The Supervisor's Observations: Comments by Bryan Karney

As a supervisor of Rosie, I can identify several benefits of having an engineering graduate student do engineering research. One primary benefit is obvious but should not be discounted for that reason: Rosie's doctoral dissertation is now a resource for the department and is a kind of repository written specifically with civil and environmental engineering as an audience. Another benefit is perhaps more intangible but is certainly important: Rosie's way has forged a path that others can follow. That is, Rosie's original research program, her course assignments, and our expectations were created with essentially no experience in conducting or supervising this kind of work. The program approach was essentially evolutionary. Having been this way before would allow a much more conscious and directed development of a research program and would allow a student who might follow to benefit from the specific knowledge and contacts gained. The assessment of, and expectations for, the research program of any future graduate students working in this area should now be more realistic, more tightly structured, and more carefully sequenced than was possible in Rosie's case. Of course, the reality is that future educational research in civil engineering will still depend, as it does in all cases, on the inspiration, dedication, ability, and resourcefulness of individual graduate students.

On a more anecdotal level, the benefits of research in one area are often difficult to predict. Although teaching a first-year-level course this term on engineering, society, and the environment, I happened to have a conversation with a particularly motivated student in electrical engineering. Out of curiosity, I asked this student about their interest and enthusiasm to learn more about the consequences of engineering activities on the natural environment. They attributed their interest to having observed a treasured fishing stream be degraded by urbanization. This led to an extended conversation related to Rosie's work and to an expectation of maintaining future contact about this subject. Certainly, this is but one case, but it is a reminder that students, as is the natural environment, are often powerfully influenced by a variety of positive and negative experiences.

The Course Instructor's Observations: Comments by Chris Kennedy

The initial ecological enhancements to the hydrology/hydraulics course prompted me to make further modifications along the same lines in the most recent session. It was recognized that larger changes were required to emphasize the ecological aspects of engineering design relating to water.

The first change was to give the reading of the fish stories greater prominence. Students were required to submit two short papers, choosing from four topics, one of which was based on the fish stories. Closer to 50% of the class, therefore, wrote about changes in river morphology from the perspective of a fish.

In addition, a further short article was added to the students' reading package. This described how a civil engineer and a biologist teamed up to save Atlantic salmon from the turbines of a hydroelectric station (Atkinson, 1999).

The next most significant change was the addition of two lectures on natural channel design. These lectures took the students beyond the traditional design of unlined channels, challenging them to include meanders, riffles, pools, and stream bank cover in the design. Most important, students learned to design for riparian flows, flooding over the banks with a frequency between 2 and 20 years, trapping sediment and nutrients and leading to features such as wetlands and ox-bow lakes (Ministry of Natural Resources Ontario, 1994). Students' knowledge of natural channel design was tested in one of six practical sessions, during which they worked for 2.5 hours on a real-world problem in teams of three.

Other course enhancements included the addition of maximum spurt-swimming speeds and low-energy sustained swimming speeds for fish (Hynes, 1972) into the general channel design procedure. Inclusion of fish-related questions on final exams and quizzes continues.

Environmental Attitudes, Engineering School, and the Future

Is It Ethical to Teach Attitudes?

When responses to the survey of engineering educators were read, one respondent explicitly questioned whether it was appropriate to attempt to teach or test attitudes at the postsecondary level. This debate is probably more familiar and accessible to university faculties other than engineering. On the faculty side, engineering is strongly influenced by industry and the corporate world to the extent that issues such as academic freedom are rarely raised in class, either explicitly or implicitly. On the student side, engineering education to some extent is shaped by having entrance standards that emphasize science and math achievement; many engineering students have a poor command of spoken and written English, so they have difficulty participating in language-based activities such as discussing the teaching of values.

Our own response to the question is, with McKeachie (1994), that "we can't avoid teaching values," and "open consideration of values issues is probably less subversive than disregarding values altogether" (pp. 374-375). In our specific context, that means we have a responsibility to understand and discuss the environmental attitudes and attitude changes of our students. McKeachie asks, "Isn't it a misuse of our position if we indoctrinate our students with our values?" (p. 375). He gives a twofold response: First, there are some values, for example, respect for each other's common humanity, that are so important that indoctrination is necessary and appropriate. Second, there are ways of helping students to understand more about values without indoctrinating them.

With increasing emphasis on sustainability in higher education, we may see a range of responses in engineering education. At present, where engineering schools are shifting course to recognize environmental problems, they seem to be mainly led by the model of sustainable development articulated in the Brundtland report (World Commission on Environment and Development, 1987). This model affords a huge range of engineering activities that do *not* rely on positive environmental attitudes: activities that simply plug environmental parameters into traditional engineering design models. Sustainable development may be a way station on the road to sustainability, but we suggest that true sustainability is going to require the conscious, rooted commitment of all members of society. That means that somewhere along the way, engineering education is going to have to change enough to recognize, affirm, and develop positive environmental attitudes in engineering students. The change is going to have to take place in a culture in which it has proved difficult to engage even with the more fundamental discussion of the value of humans compared with machines (Hyde, 1994, p. 84).

What Chance for Empathy-Oriented Environmental Learning?

Will empathy-oriented learning become accepted practice in engineering education? At a practical level, the answer depends on judgements of the efficacy of empathy-oriented learning. Engineering educators are acutely conscious of the pressures of time in the undergraduate curriculum. There is a constant tension between teaching specialized techniques and teaching general engineering principles. In developing curriculum, engineering educators need to position their programs between research and practice, recognizing that many undergraduates will never go on to advanced degrees but that those who do will need a solid theoretical foundation. University programs must also recognize the niche of engineering technologists and technicians (respectively, 3-year and 2-year community college programs) who fill the need for basic engineering functions by using a highly practical curriculum.

Furthermore, in the area of environmental concerns, most solutions are interdisciplinary, and any environmental content in engineering programs has to be justified by proving that it is not better done by other, more specialized professionals.

For proof that a curriculum component belongs in engineering, decision makers ask the following questions:

- Is this component traditionally part of engineering?
- Is the prerequisite knowledge part of engineering?
- Is it at the appropriate level of abstraction/complexity?
- Is it in demand by engineering employers?
- Is it a good response to changing circumstances?

Empathy-oriented learning will have a hard time passing these tests. It would need to be shown that empathy-oriented learning does form engineers who practice in a more environmentally sensitive way; even if true (and who knows?), proving this through research would be a long and difficult task. Also, it would need to be accepted that sustainability is so important that such engineers are needed. In the meantime, the best chance for empathy-oriented learning in engineering is that it may be incorporated by engineering educators who are prepared to adopt it without proof of its efficacy, either because it intuitively appeals to them or because its real-world dimension is motivating for their students.

For engineering educators who want to try empathy-oriented learning, our study provides some ideas for preparing materials with the least effort for the overstretched professor. Although we took the approach that an engineering graduate student learned about hydrology, learned about fish, and tried to illustrate the connections, our experience suggests that this is not the only approach. It would probably be possible for an engineering instructor to give the relevant course delivery materials to a graduate student with a biology background and employ them to construct illustrative problems or stories. The graduate student could be further employed to suggest ways of assessing whether the students have understood the environmental aspects of these materials, mark the assessment instrument, and recommend changes to the materials and the instrument.

Conclusion

An apparently simple curriculum enhancement of an engineering course led us to learn about what life forms we share the planet with and how we can understand their needs, as well as who our students are and how we can understand their learning processes. It also led us to ask questions about the meaning of engineering and environment. At a spiritual level, and to revisit the "mattering" framework presented near the beginning of this article, do we think that sustainability can ultimately be achieved through the technological manipulation of resources? The concept of an eternity of recycling—with greater and greater cleverness—the materials of the planet is an expression of that city where God is not needed because humans have made a name for themselves. It is an expression of a world in which there is no faith because, in the denial of authentic otherness, intellect is not enlightened by love. If empathy-oriented learning has something to offer to engineering education, it is not a quicker way to learn exploitation but rather a slow path to choosing against seeing everything as resources. Could we still name ourselves engineers? Or name ourselves at all?

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Rosamund A. Hyde has recently completed her doctorate in civil engineering at the University of Toronto, with a dissertation on educating engineers for environmentally sensitive practice. Her research interests include the response of higher education to environmental change and the transition from professional training to professional practice.

Bryan W. Karney is a professor of civil engineering at the University of Toronto. His primary research area relates to the performance and behavior of water resources systems, with a particular emphasis of modeling the response of hydraulic and hydrologic systems. The larger issues of education, environmental sensitivity, and educating for environmental sensitivity are long-term passions. He is currently acting chair of the Collaborative Program in Environmental Engineering and is an associate editor of the Journal of Hydraulic Engineering *for the American Society of Civil Engineering.*

Christopher A. Kennedy is an assistant professor of environmental engineering at the University of Toronto, where he teaches courses in hydrology, hydraulics, statistics, and groundwater. His research interests include sustainable urban infrastructure and subsurface contamination/remediation. He holds degrees in civil engineering from the University of Waterloo, Canada, and Imperial College, London, UK.