Development of Environmental Knowledge and Attitudes in Engineering Students

Christopher Kennedy
Rosamund Hyde
Bryan Karney
University of Toronto

A test was administered to 102 engineering students to ascertain how engineering education influences their environmental knowledge and attitudes. Answers to definitional and factual questions in a forced-answer section demonstrated that students were improving their technical knowledge, but responses to more subtle questions were mixed. Answers to attitudinal questions exhibited a trend towards increased environmental awareness. For open-ended questions, posttest results showed an increase in knowledge of engineering work. Over 80% of the students considered themselves to have a caring attitude toward the environment, with the "three R's" and green transportation choices most commonly cited. Engagement in research, education, or advocacy doubled from pretest to posttest. Air pollution and solid waste disposal most frequently influenced students' attitudes toward the environment. Outdoor experiences were the most frequently mentioned source of information; university courses rose from 4% to 15% on the posttest. Only 40% of the students could name an environmental role model.

Keywords: *engineering education, environmental knowledge, environmental attitude*

Most professional engineering bodies expect practicing engineers to be committed to the environment, to the extent of acting as environmental advocates. To meet such expectations, engineering students need to achieve learning goals that are both cognitive (knowledge related) and affective (attitude related). This article reports on the results of one instrument to measure the extent to which engineering students in undergraduate programs at the University of Toronto realize these goals. The students surveyed were in civil engineering (both general and environmental streams), mineral engineering, and the environmental streams of chemical and mechanical engineering.

The measurement of attitude toward the environment has received significant attention in the environmental education literature. Dunlap and van Liere (1978) developed an instrument, the New Environmental Paradigm, for measuring respondents' worldviews with respect to the environment. Likert-type scale instruments assessing several dimensions of environmental concern have been developed and applied by Steiner and Barnhart (1972), Kuhn and Jackson (1989), and Berberoglu and Tosunoglu (1995). Changes in the attitudes of university students with time have been measured: Thompson and Gasteiger (1985) compared environmental attitudes between university students in 1971 and 1981; Hess-Quimbita and Pavel (1996) followed 18,000 students from the freshman class of 1985 past graduation. A shorter term study of attitudinal change, over the duration of one environmental studies course, was undertaken by Smith-Sebasto and D'Costa (1995), who found that students completing the course showed an increase in internal locus of control for reinforcement for environmentally responsible behavior and an increase in self-reported environmentally responsible behaviors relative to a control group.

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Although there have been many studies of attitude changes in environmental education, as mentioned above, a review of this literature by Hyde (1999) did not uncover any such studies focused on engineering students. Consequently, several faculty members teaching environmental engineering courses at the University of Toronto designed a survey for examining changes in students' affective learning. The surveys also provided an opportunity to examine students' technical knowledge of several fundamental civil and environmental engineering concepts outside of a formal examination procedure. In the course of an undergraduate curriculum, students learn a vast amount of material—and become adept at applying this knowledge under examination conditions. But just how well are environmental engineering principles and attitudes ingrained into students' overall knowledge bases?

Method

The survey was first administered to 102 students at the beginning of their 2nd year of undergraduate study; the identical test was then given to the same group of students 18 months later, near the end of their 3rd year. To provide a greater context for evaluating the results, the fixed-problem portion of the test was also administered to the majority of the faculty in the environmental section of the department of civil engineering. Over their 2nd and 3rd year, participating students took several environmental and water resources engineering courses, in which they were instructed on material covered on the survey. These courses included engineering ecology, hydrology and hydraulics, chemistry, municipal engineering, and transportation engineering. A few of the students (those in the environmental engineering stream) also took a course in environmental risk assessment.

The first section of the survey consisted of 26 forced-answer questions (see Table 1). The students were given short statements and asked to express the degree to which they agreed with each statement. Their responses were recorded on a Likert-type scale ranging between 1 (*strongly agree*) and 5 (*strongly disagree*). The students were also offered the option of answering 0 (*insufficient knowledge to answer*) (see Table 2). At the beginning of the survey, students were given a relatively detailed list of instructions to aid in the interpretation of statements and the formulation of their answers (see Table 3).

The second part of the survey comprised several open-answer questions. Students were asked to list the five most significant activities that they would expect to conduct as practicing engineers. They were questioned about their attitudes toward the environment, the life experiences they believed influenced their attitudes, and their environmental role models.

Results

The students' responses to the forced-answer questions are discussed first, followed by a reflection of the environmental engineering professors' reactions to the same questions. After this, the students' answers to the more open-ended questions are discussed in somewhat greater detail.

Forced-Answer Questions

The 26 structured questions were assessed with respect to the percentage of students indicating knowledge of the statement and the percentage of students giving the correct or preferred answer where appropriate (see Table 4). For the purpose of analysis, the statements have been classified as definitions, facts, technical questions with opinion, and attitudinal statements (see Table 4).

To help judge whether there was significant change between the fall 1999 pretest results and the posttest answers, comparison was also made with the pretest results of the next class of students. These students took the pretest in fall 2000. There was remarkable consistency between the two sets of pretest results, with percentage responses being similar for approximately 75% of the questions. The main exceptions to this trend were Questions 1, 3, 4, 6, and to a lesser degree 20 and 25. The extent of observed changes between the pretest (fall 1999) and the posttest depended on the type of statement posed.

Answers to definitional and factual questions in the forced-answer section generally demonstrated that students were improving their technical knowledge. This was exhibited by fewer students answering 0 (*insufficient knowledge to answer*) and a general trend toward correct answers. The responses to Statement 11 provide a good example (Figure 1). The pretest responses to this statement ("The water level in a river will often continue to rise for a few hours after rain has fallen in the upstream catchment area") confirmed the impression that many undergraduate students enter the program with weak intuitive senses of hydrological systems. Over one third of the class indicated a lack of knowledge relating to river water levels and rainfall in

Table 1. Statements Assessed by Students in Part A of the Survey

1. An ecosystem is an arbitrarily defined area of land where plants and animals coexist.
2. Actions taken to prevent the formation of pollution from engineering processes always save money.
3. Environmental systems can be readily modeled and understood.
4. Sustainable development is possible with the current level of human population growth.
5. The reduction of biodiversity in an ecosystem decreases the stability of the ecosystem.
6. When species compete for identical resources in an ecosystem, one species will always succeed, causing extinction of the other species.
7. Levels of contaminant toxicity in lakes and rivers that are considered acceptable to humans, are generally also safe for other life forms.
8. Deep subsurface injection of liquid wastes, e.g. into the bedrock 1 km below ground surface, is an acceptable practice since it removes potentially harmful liquids from direct human exposure.
9. Dilution of contaminants is the best solution to pollution.
10. Despite its negative environmental impacts, the convenience, comfort and economy of the automobile are too important for this mode of transport to be abandoned by city dwellers.
11. The water level in a river will often continue to rise for a few hours after rain has fallen in the upstream catchment area.
12. A flux is the rate of transfer of some quantity per unit area, or a net rate of transfer over an entire surface.
13. A watershed is a portion of land from which surface water drains through a specified point.
14. Carbon dioxide and methane are two primary greenhouse gases that are thought to be causing global climate change.
15. Recycling schemes for which operation costs exceed the value of recycled materials should be closed down since they are an unnecessary financial burden on local taxpayers.
16. When humans interfere with nature, it often produces disastrous consequences.
17. Most problems can be solved by applying more and better technology
18. The positive benefits of economic growth far outweigh any consequences.
19. Environmental laws are too strict if the economy suffers.
20. It is always irresponsible for engineers to design systems that they know will fail.
21. Roads are a critically important part of the runoff system and their hydraulic characteristics must be carefully designed.
22. Adding many extra pipes to “loop” a water distribution system is both prudent and allows development of efficient and effective supply systems.
23. A dose-response curve is generally nonlinear.
24. Since the environmental impacts of an engineering project can almost always be mitigated to a level allowed by law, there is little need to consider different types of solutions.
25. The cumulative environmental effects of a proposed new highway are generally insignificant.
26. pH is a measure of hydrogen ion concentration.

Table 2. Likert-Type Scale for Assessment of Survey Statements

0 = *insufficient knowledge to answer*
1 = *strongly agree*
2 = *weakly agree*
3 = *neutral*
4 = *weakly disagree*
5 = *strongly disagree*

catchment areas. The posttest results showed a significant (and reassuring) shift in responses toward strongly or weakly agreeing with the statement. Similarly strong indications of technical learning were exhibited in answers to Questions 5, 12, 14, 21, and 23.

Students’ responses to more subtle technical questions were mixed. For example, following courses in hydrology and hydraulics and municipal engineering, students should have learned that many hydraulic structures are designed with the knowledge that their capacities will be exceeded by extreme events. That is, such systems must often be designed with the knowledge that they will sometimes fail, but when they do, they must fail safely (i.e., so-called safe-fail systems). Students’ answers to Statement 20 (“It is always irresponsible for engineers to design systems that they know will fail”) did show movement toward this understanding (Figure 2). But on the posttest, 23 students still thought that it is irresponsible for engineers to design systems that they know will fail. This response likely reflects a strong prior opinion that if an engineer’s system fails, that engineer made a mistake. As Slovic and Lichtenstein (1971) noted some time ago, initial estimates or opinions often overly constrain and bias adjustments in the light of new data.

Several of the questions posed are particularly interesting because they touch on complex environmental issues that require technical knowledge but are also

Table 3. Additional Instructions for Part A of the Test

- Please do not guess! There are several questions where we would be surprised if you did have sufficient knowledge to assess the statement.
- Don't tell us what *you think we want* to hear—give us *your* opinion. You are only given credit for participation in this test; no papers will be marked.
- Interpret terms such as "reasonable" and "generally" as best you can, based on your experience.
- Interpret each statement in its entirety. If there is any part of a statement that you disagree with, then you should lean towards "disagree" in your answer.
- If you do not understand a word or term in a statement, then answer "insufficient knowledge to answer."
- There is space under each question to leave a comment if you wish. This is not mandatory.
- When you later reflect back upon this test please remember that some of the statements are wrong!!!

Table 4. Summary of Results to Forced-Answer Questions

			% of Students Indicating Insufficient Knowledge			% of Students Giving the Correct or Preferred Answer		
No.	Type	Answer or Instructor's Preference	Pretest Fall 1999	Posttest	Pretest Fall 2000	Pretest Fall 1999	Posttest	Pretest Fall 2000
1	Definition	5	5.2	1.7	1.6	8.6	17.2	19.2
2	Technical/opinion	2	1.7	0.0	2.4	27.6	15.5	22.4
3	Technical/opinion	5	3.4	1.7	8.8	22.4	39.7	32.0
4	Technical/opinion	5	8.6	6.9	18.4	27.6	34.5	24.0
5	Factual	1	31.0	10.3	20.8	48.3	65.5	48.0
6	Factual	4 or 5	6.9	8.6	3.2	41.4	39.7	52.0
7	Factual	5	1.7	6.9	4.8	53.4	67.2	60.8
8	Technical/opinion	5	13.8	24.1	16.8	51.7	44.8	54.4
9	Technical/opinion	5	8.6	10.3	4.0	44.8	51.7	48.0
10	Attitudinal	NA	0.0	0.0	2.4			
11	Factual	1	53.4	12.1	43.2	15.5	39.7	14.4
12	Definition	1	50.0	20.7	44.8	22.4	36.2	24.0
13	Definition	1	70.7	20.7	75.2	3.4	36.2	5.6
14	Factual	1	13.8	3.4	19.2	31.0	53.4	33.6
15	Technical/opinion	4	1.7	3.4	0.0	48.3	25.9	46.4
16	Attitudinal	NA	1.7	3.4	2.4			
17	Attitudinal	NA	0.0	0.0	0.8			
18	Attitudinal	NA	3.4	1.7	1.6			
19	Attitudinal	NA	6.9	5.2	8.0			
20	Factual	4	3.4	0.0	0.8	5.2	12.1	8.0
21	Factual	1	24.1	8.6	36.0	48.3	67.2	36.8
22	Factual	1	63.8	25.9	62.4	10.3	15.5	5.6
23	Factual	2	86.2	63.8	80.8	6.9	8.6	7.2
24	Technical/opinion	4 or 5	5.2	6.9	6.4	82.8	86.2	85.6
25	Factual	5	8.6	5.2	14.4	39.7	58.6	53.6
26	Definition	5	6.9	5.2	3.2	15.5	8.6	4.8

Note: NA = not applicable.

highly subject to opinion or attitude. Questions 3, 8, and 9 are good examples of such questions (or perhaps also Questions 2, 4, 15, and 24). The responses to Question 8 were particularly interesting (see Figure 3). The question asked students whether the deep subsurface disposal of liquid wastes is an acceptable practice. After having been introduced to basic concepts in groundwater flow and subsurface contamination, more students in the class indicated that they had insufficient knowledge to respond to the question. This may be a realistic response indicating an increased awareness of the complexity of the issue.

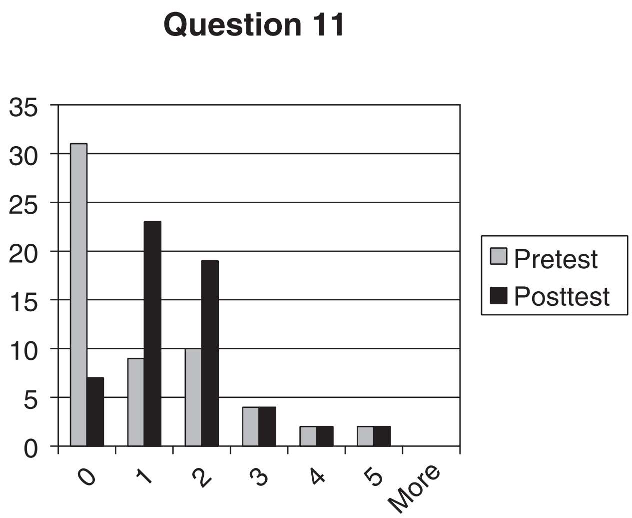

Figure 1. Students' Responses to Statement 11 ("The water level in a river will often continue to rise for a few hours after rain has fallen in the upstream catchment area")

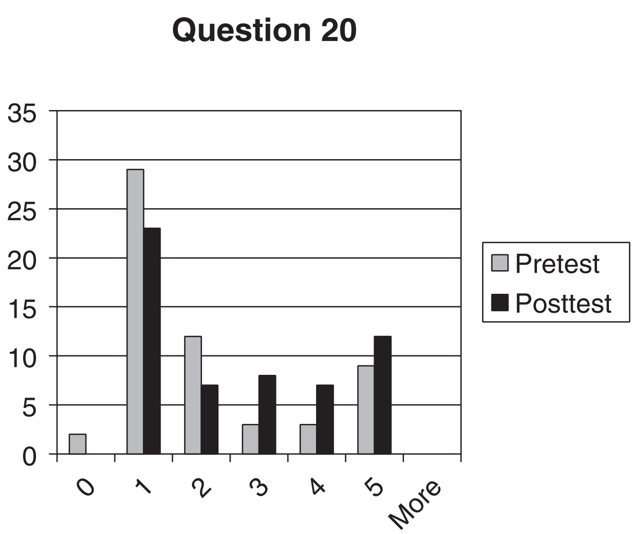

Figure 2. Students' Responses to Statement 20 ("It is always irresponsible for engineers to design systems that they know will fail")

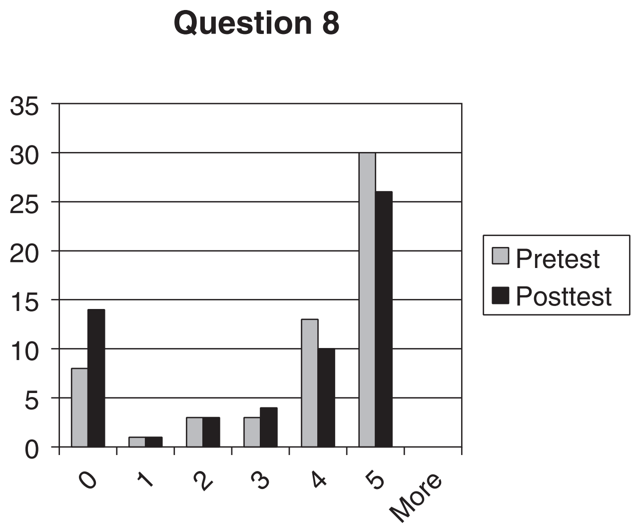

Figure 3. Students' Responses to Statement 8 ("Deep subsurface injection of liquid wastes, e.g. into the bedrock 1 km below ground surface, is an acceptable practice since it removes potentially harmful liquids from direct human exposure")

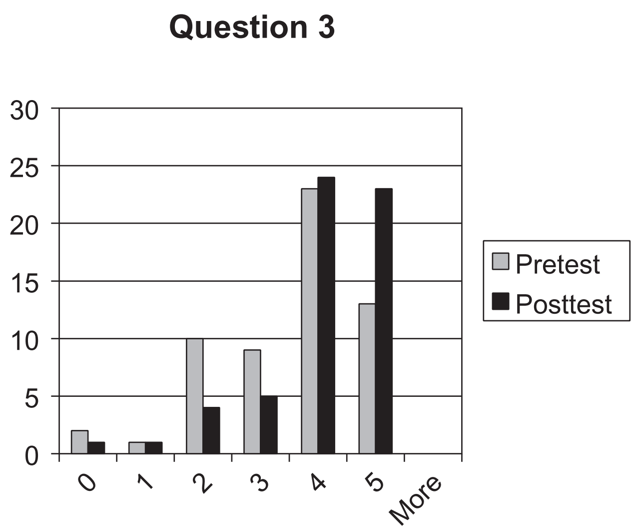

Figure 4. Students' Responses to Statement 3 ("Environmental systems can be readily modeled and understood")

Along similar lines, responses to Statement 3 ("Environmental systems can be readily modeled and understood") indicated that on the posttest, more students disagreed with this statement (Figure 4).

Answers to attitudinal questions generally exhibited a trend toward increased environmental awareness. For example, there was a significant increase in the number of students strongly disagreeing with Statement 17 ("Most problems can be solved by applying more and better technology") (see Figure 5). This statement is clearly broad and ambiguous. Nevertheless, a similar response was exhibited to the more specific Question 10, which examined students' attitudes toward the automobile (see Figure 6).

Comparisons of students' answers to those given by faculty members in civil engineering revealed both expected and unexpected outcomes. In general, for those questions for which there was a general shift in

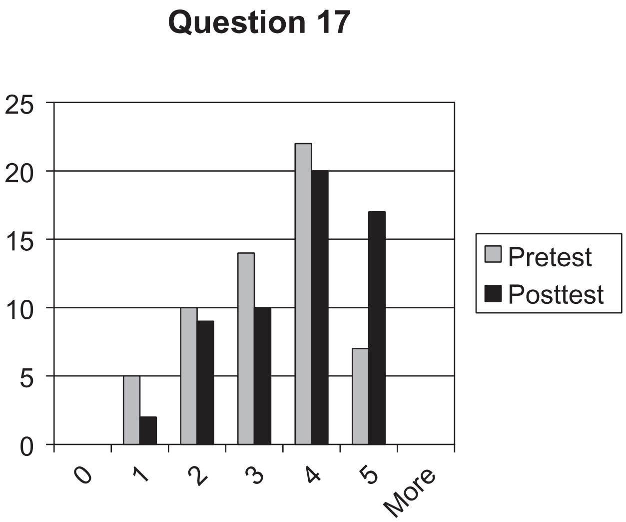

Figure 5. **Students' Responses to Statement 17 ("Most problems can be solved by applying more and better technology")**

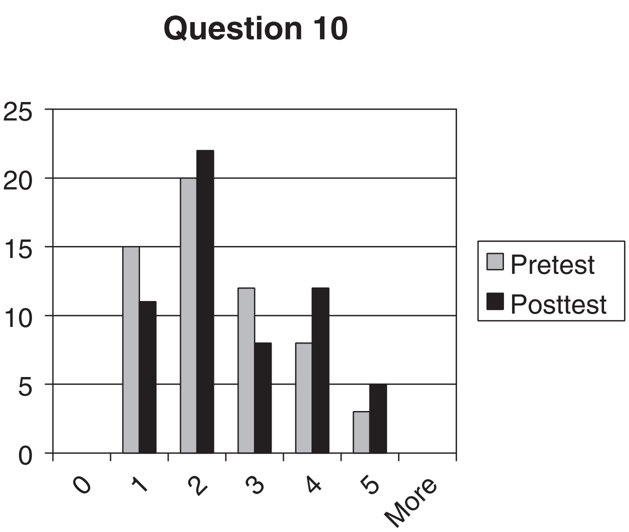

Figure 6. **Students' Responses to Statement 10 ("Despite its negative environmental impacts, the convenience, comfort and economy of the automobile are too important for this mode of transport to be abandoned by city dwellers")**

opinions, it was likely that the new opinions better reflected the opinions of the engineering faculty. Certainly, this was not a surprising result and no doubt reflects socialization into a (locally) dominant culture. However, there were also some interesting differences. Some of these differences related to an understanding of the facts or definitions, and some of them reflected a significant difference in perception.

For example, one of the fairly straightforward definitions was given in the first statement: "An ecosystem is an arbitrarily defined area of land where plants and animals co-exist." There was a strong tendency for the students to accept this statement, whereas the professors rejected it. The part of the statement involving both plants and animals coexisting appears to have been sufficient reason for the students to accept the answer. However, subsequent discussion of the statement among the faculty members indicated that the statement was hung up on not just one point but two ("arbitrary" and "land"), making it too inaccurate to accept.

An interesting parallel issue of definition was raised by Statement 26, involving pH ("pH is a measure of hydrogen ion concentration"). Here, the "nonchemistry" faculty members tended to side with the students that there was much to agree with in the statement; by contrast, this statement was strongly rejected by faculty members with deeper (routine) exposure to chemistry. Clearly, the issue of learned distinctions is a key one in education and learning.

A difference in attitudes was raised by the reactions to Statement 2: "Actions taken to prevent the formation of pollution from engineering processes always save money." In this case, 2nd-year students tended to accept the statement, whereas there was a noticeable shift among 3rd-year students to reject it (e.g., more than double strongly disagreeing in the later-year students). Interestingly, the professors as a group were much more ambivalent about the statement, tending to respond in the middle ranges (2 and 4). Of course, interpreting purely numerical output is something of a tricky process, so it is logical at this point to turn to an analysis of the open-ended questions.

Open-Ended Questions

First question: List the five most significant activities that you would expect to conduct as a practicing engineer. On the pretest, the range of responses to this question was broad, from one-word summaries to fully developed paragraphs. Most students gave answers at two levels: what they would do (means) and why they would do it (ends) (see Table 5). More means were given than ends, by a ratio of 5 to 3. Thirty students mentioned only means, and 1 student mentioned only ends. Almost all the students filled in all the five spaces provided, which gave a total of about 500 responses. However, because some of the student an-

Table 5. Students' Perceptions of Activities Undertaken by Professional Engineers

Pretest				Posttest		
Number of Responses	Rank	Category of Response	Substance of Response	Substance of Response	Number of Responses	Rank
Means						
85 (22%)	1	Primary design	Design, plan, propose, draft, choose materials, choose energy sources, choose methods, develop	Design new provincial/national highway system; design integrated public transit; design federal sterile areas; engineering design; environmental considerations; consider environmental effect; design infrastructure; plan, schedule; environmental decision making; city planning; design infrastructure such as bridge/dam that would have impact on environment; sustainable design/design (aesthetics); structural design; pipeline design; traffic planning; consider several options of a design; structural engineering and design; safe design; design or simulate things; safety design; sustainable designs for cities and buildings	63 (20%)	1
61 (16%)	2	Research	Research, study, analyze, calculate, experiment, model, forecast, find new method, evaluate data	Advance knowledge in field; lifecycle assessments; research on minimizing environmental impact; traffic flow simulation; evaluation and decision making; research and conduct environmental studies; research on methods to improve treating groundwater contaminants and wastewater	33 (11%)	4
46 (12%)	3	Work with people	Manage, supervise, consult, collaborate, work on projects, be involved	Resources/labor management; teamwork; structural consultant; field project manager; construction management; perform tasks on time and budget; time management for projects; interacting with other engineers; construction management; engage in meaningful societal and business relationships; networking; decision making; interaction with society; act as team leader	52 (17%)	2
38 (10%)	4	Redesign	Redesign, improve, repair, remediate, rehabilitate, upgrade, modify, maintain	Mitigation; rehabilitate highways; rehabilitate buildings; improve transportation system; finding better solutions to problems; improve tanning of leather	16 (5%)	7
38 (10%)	5	Gather data	Test, visit, inspect, observe, understand, measure, survey, fieldwork, prospect, assess	Environmental impact analysis (13 responses); monitor; site investigations; ensure safety regulations are met	27 (9%)	5
27 (7%)	6	Construct	Construct, fabricate, produce, build, create	Working practically; construct buildings in a more effective and safe way; bridge construction	5 (2%)	11
24 (6%)	7	Instruct	Teach, learn, inform, persuade, advocate, encourage, influence, listen, protest, make presentations, advise	Debate; become involved in legislative process for engineering; environmental issues; constant education; guide younger engineers; educate about environment; mentoring and passing on wisdom; promote environmental sustainability; promote process or product; share knowledge; master basics; promote better alternatives; educate people on safe environmental practices; encourage safety programs; encourage students; provide hands-on experience; technical support	25 (8%)	6
22 (6%)	8	Control	Control, guide processes or systems, productivity, quality, solve problems, troubleshoot	Quality control; optimize; finding new solutions to improve human life without impacting the environment	14 (4%)	8
16 (4%)	9	Other[a]			34 (11%)	3
12 (3%)	9	Administration	Administration, document, report, record, communicate	Publishing journals; interpersonal skills, communication, material ordering; drawings; writing requests for proposals	9 (3%)	10

10 (3%)	10	Financial	Costing, bidding, budget, financial feasibility, marketing	Finance; investigate effect of tariffs and taxes on trade and how these could be used to enforce global environmental responsibility; economic design; collecting money; consider environmental effect; estimate; bid; financially analyze; quantity surveying; profit assessment; economic analysis	25 (8%)	6
8 (2%)	11	Act professionally	Honesty, creativity, do one's best, avoid/admit to errors	Moral responsibility; sound judgment; common sense; technical ability; ethical conduct; ethical behavior; responsible for their design; responsible for people's safety; follow the law	11 (4%)	9
Ends						
110 (48%)	1	Protect environment	Understand environment; consider environment; enhance environment; protect environment; rehabilitate environment	Prevent pollution; reuse materials; reduce residuals; reduce environmental impact; respect the environment; pollution control; reduce air pollution; improve quality of water; protect environment; recycle; save resources; be aware of environmental impacts; nurture the environment	24 (41%)	1
42 (18%)	2	Help people	Help people; protect people; health and safety; improve living standard; make a positive difference; work for development	Ensure safety; safety control; public safety; safety considerations; use technology to improve the living conditions of the two thirds world countries	12 (20%)	2
36 (16%)	3	Cost-effective	Be cost-effective; be cost efficient; make economical decisions; consider economy	Maximize profit; reduce cost	8 (14%)	3
16 (7%)	4	Make efficient/ effective designs		Efficient design practices	2 (3%)	6
9 (4%)	5	Meet job needs	Make money; have a job; own company; have power; boss people around		5 (8%)	5
9 (4%)	6	Meet societal need/serve society[b]		New solutions to global problems; use knowledge to improve society; contribute to sustainable projects in cash and kind; reduce energy consumption; nice aesthetic designs	6 (10%)	4
4 (2%)	7	Apply preventive methods			2 (3%)	6
3 (1%)	8	Meet client/ employer need			0	7
2 (1%)	9	Meet family/ personal need			0	7

Note: Total number of means-related responses on the pretest = 387. Total number of means-related responses on the posttest = 314. Total number of ends-related responses = 231.

a. The "other" category on the pretest included the following responses: meet people; travel; geotechnical engineering; go golfing with clients; upgrade environmental standards of structures, etc.; specification design and control; find ways to meet updated environmental and building codes; find out if my product meets specification/competitiveness; mining for different minerals; bridge gap between disciplines; learn from nature for design purposes; improve tie between technology and ecology; relaxing, sustainability; and CEO of a company. The "other" category on the posttest included the following responses: applying technical knowledge, prevent, correct, reduce, save, embrace every technology that leads to more sustainable environment, transportation, municipal, treatment of water, waste treatment and water resource, no procrastination, durability of the project, long-term costs, profit, environmental impacts, transportation systems, drinking (2 responses), partying, taking aspirin, helping small villages in India get access to clean water, helping India's cities reduce air pollution, clean water supplies, use computers, solve differential equations, voluntary works either in Canada or overseas, engineering, waste treatment, reduce the need to use automobiles, manufacturing or process engineering, sustainable development, sustainable fuel sources, going on break or lunch, golfing, and actual work.

b. Societal needs listed included the following responses: more women in engineering, create more jobs, reduce traffic congestion, increase awareness of engineering.

swers were complex, a total of 618 responses were coded.

Although the separation into means and ends may seem arbitrary, these assignments largely followed the students' responses. For example, in the phrase "redesign a road to make it more cost-efficient," the first part is taken as means and the second part is taken as an end. The most popular means were design and planning activities, followed by research, study, and experimentation activities. The most popular end was understanding and protecting the environment, followed by helping and making a difference.

On the posttest, the most notable change was the increase in knowledge of engineering work reflected by the students' answers. They had many more activities to name, and as a result, means were named much more often than ends on the posttest. The ratio of means to ends increased to over 5 to 1.

Second question: Do you consider yourself to have a positive, caring attitude toward the environment? Give two or more examples to support your answer. Some students were quite vehement about their environmentally friendly behaviors. Out of the 102 responses on the pretest, 84 were easily categorized into "yes" (74), "very strongly yes" (4), and "no/not really" (6) (see Table 6). The other responses were more ambivalent. Responses on the posttest were similar to those on the pretest. The data show a small increase in the percentage of students who did not consider themselves to have positive attitudes toward the environment (7% to 11%). But this change was small and could be either an artifact of the classification process or a result of random variation in the data.

The most popular evidence given for environmental caring was in the "three R's" category: "I reduce, reuse, and recycle." The second most popular was "I make green transportation choices." Somewhat surprisingly, on the pretest, the third-place reason was "I don't litter" (17). Only 7 students mentioned engaging in research, education, advocacy, or activism on the pretest. But on the posttest, engagement in environmental activity and maintaining an awareness of environmental issues were jointly in third place. Both of these categories of response doubled relative to the pretest.

Third question: What life experiences influenced your attitude toward the environment? The students wrote with passion about their life experiences. The analysis focuses on three aspects of the students' responses to this question: how they described the impact of the influence, what environmental issues they mentioned, and what sources of information they mentioned (see Table 7).

In describing the impact of the influence, the most frequent responses on the pretest were "[something] changed my attitude" (13), "[something] informed me" (8), and "[something] made me realize there is a problem" (6). This third response was also common on the posttest, whereas responses along the lines of "I saw or experienced . . ." were most frequent.

Air pollution was the issue most frequently mentioned on the pretest (13), followed by solid waste and landfills (6) and a lack or loss of trees (6). Global warming and climate change was seventh in frequency (3).

On the posttest, air pollution and solid waste were again frequently mentioned. References to water treatment and drinking water issues doubled on the posttest; this may be attributed to the Walkerton crisis in the spring of 2000. (Seven people died from contamination of the drinking water supply in Walkerton, Ontario—an issue that received considerable media attention in the province.) Interestingly, significant mentions of dirty cities occurred for the first time on the posttest. But surprisingly, and disappointingly, mentions of global warming and climate change disappeared.

Experiences of the outdoors (hiking, camping, canoeing) were the most frequently mentioned source of information (26), followed by visiting places with bad environmental conditions (20) and books, TV, and the news media (11). Responses mentioning university courses rose from 4% on the pretest to 15% on the posttest.

Fourth question: Name the environmentalist whom you most respect as a role model. The fourth question was a new addition to the 2000 pretest; it did not appear on the 1999 pretest. The question was motivated by an education article (Newhouse, 1990) that indicated that the use of role models is an effective environmental education strategy. Do engineering students have respected environmental role models, and if so, who are they? The responses to this question on the 2000 pretest and 2001 posttest are shown in Table 8. Both classes were reasonably similar in response: 26% to 30% of students gave no answer, 36% to 39% indicated a lack of a role model, and 38% to 44% named role models.

The 41 students on the 2001 posttest who named environmental role models gave 44 names (3 gave two

Table 6. Students' Reflections on Their Attitudes Toward the Environment

Do You Consider Yourself to Have a Positive, Caring Attitude Toward the Environment?	Pretest 1999 Number of Responses	Pretest 1999 % of Responses	Posttest 2001 Number of Responses	Posttest 2001 % of Responses
Answers that were easy to categorize				
Yes	74	88	73	88
Yes, very strongly	4	5	1	1
No or not really	6	7	9	11
Totals	84	100	83	100
Behaviors mentioned as proof of caring				
I reduce, reuse, recycle	98	54	69	48
I make green transportation choices	25	14	18	13
I don't litter	17	9	5	3
I buy green	9	5	6	4
I engage in research, education, advocacy, activism	7	4	12	8
I cultivate/protect plants	7	4	3	2
I maintain awareness of environmental issues	6	3	12	8
I plan to . . . (environmentally responsible behavior)	5	3	3	2
I try to think of ways to help the environment	4	2	0	0
I clean up other people's litter	4	2	1	1
Posttest only				
I spend time in nature or with animals			4	3
I believe in [environmental value/protection]			7	5
I help humans			1	1
No examples given			3	2
Totals	182	100	144	100

names each). Also mentioned once each were "my biology teacher (high school)," "my Physics teacher in OAC," and "you, sir."

Reflections on the Students' Comments

The students' responses to the open-ended questions were diverse and fascinating to read in their entirety. For example, for the question on engineering activities, there was clearly a wide range of knowledge about the realities of engineering work. Although overall, the categories of activities occurred in proportions that are close to real life, many of the individual responses presented less than a complete picture of an engineering job. Also, out of 387 "means activities" mentioned, only 10 were explicit mentions of financial aspects of engineering (costing, budgeting, financial feasibility, etc.). Interestingly, financial trade-offs were recognized much more clearly in the "ends" dimension of the responses (out of 231 ends, 36 were mentions of making economical designs, considering the economy, or being cost-efficient).

This analysis of the answers to the open-ended questions might lead us to

- choose some of the better informed respondents to the question on engineering activities and arrange for them to talk to other students about their work experiences and
- integrate into the curriculum more references to the financial aspects of engineering work.

For the question on environmental attitude, recycling was a highly popular response (47 mentions). One student explicitly stated that if everyone recycled, it would make a big difference, which is true. On the other hand, the 12 students (on the posttest) who engaged in research, education, advocacy, and activism come closer to the professional expectations expressed by Professional Engineers Ontario in its environmental guidelines. Is there a way to move engineering students along that spectrum?

Perhaps recycling could be an effective entry point for discussions about lifestyle and societal choices; students' comments on why they started recycling could raise some interesting points about education and positive example. Market problems related to recycling could also be explored. Moreover, the relative environmental effects of various lifestyle choices could be included in a discussion on sustainability.

Table 7. Life Experiences That Influenced Students' Attitudes Toward the Environment

List One or More Life Experiences That You Think Have Most Influenced Your Attitude Toward the Environment	Pretest 1999		Posttest 2001	
	Number of Responses	% of Responses	Number of Responses	% of Responses
Type of impact of influence				
Something changed my attitudes	13	30	2	3
Something informed me	8	18	2	3
Something made me realize there is a problem	6	14	11	18
Something distressed me	5	11	4	7
Something moved me to commitment	4	9	2	3
Something gave me a positive paradigm	3	7	4	7
Something awed me	2	5	0	0
Something moved me to initiate action	2	5	0	0
Something gave me hope	1	2	0	0
Something involved me	0	0	4	7
Something gave me enjoyment	0	0	5	8
I value or care about something	0	0	5	8
I saw or experienced . . .	0	0	20	33
Something made me love . . .	0	0	1	2
Totals	44	100	60	100
Issues mentioned				
Air pollution	13	22	12	20
Solid waste/landfill	6	10	7	12
Lack/loss of trees	6	10	4	7
Oil spills	4	7	5	8
Water treatment/drinking water	4	7	12	20
Acid rain	3	5	1	2
Global warming/climate change	3	5	0	0
Nuclear power	2	3	1	2
Lead poisoning	2	3	0	0
Litter	2	3	1	2
Ozone depletion	2	3	2	3
Increased skin cancer	2	3	0	0
Species extinction	2	3	4	7
No swimming	2	3	0	0
Resource shortage	2	3	0	0
Population	1	2	1	2
Allergy	1	2	0	0
No fishing	1	2	0	0
Dirty cities			6	10
Catastrophe			2	3
Materialism			2	3
Totals	58	100	60	100
Sources of information about the environment				
Experiences of outdoors	26	28	14	16
Visit places with bad environmental conditions	20	22	22	26
Books, TV, news media	11	12	10	12
Visit places with good environmental conditions	10	11	15	17
Workplace experience (salaried and volunteer)	8	7	4	5
Formal education, preuniversity	7	8	4	5
Family members	6	7	3	3
University courses	4	4	13	15
Relationships with animals			1	1
Totals	92	100	86	100

Table 8. Students' Environmental Role Models

Name the Environmentalist Whom You Most Respect as a Role Model	Pretest (class starting 2000)	Posttest (class starting 1999)
No answer	26%	30%
Nobody	13%	11%
Don't know any environmentalist role models	23%	28%
Total who named an environmental role model	38%	44%
David Suzuki	25%	12%
Professors	2%	11%
Others	10%	33%

Role models mentioned by name on the 2001 posttest

David Suzuki (11 mentions): Canadian environmental advocate and professor
Bill Vanderburg (6 mentions): University of Toronto professor of society and technology
Bryan Karney (3 mentions): University of Toronto professor in environmental engineering
Namir Khan (3 mentions): University of Toronto professor of society and technology
Jane Jacobs (3 mentions): Canadian urbanist and author
Dalai Lama (3 mentions): Exiled spiritual leader of Tibet
Ralph Nader (2 mentions): U.S. consumer advocate and former presidential candidate
Kevin Callan (2 mentions): Canadian canoeing expert, author, and TV guest
Bob Hunter (1 mention): Unknown
Dr. Jerri Neilson (1 mention): Author of *Ice Bound*
Jane Goodall (1 mention): Primatologist
Arundhatti Roy (1 mention): Author
Linus Pauling (1 mention): Scientist
Jamie Laut (1 mention): Engineer at Petro-Canada
James Lovelock (1 mention): Originator of Gaia theory
D. Nowlan (1 mention): Successfully campaigned against expressways in Toronto

For example, does using a recycling box redeem using a sport-utility vehicle? If not, is using both an untenably inconsistent position? If so, which should be abandoned?

For the question about influences on environmental attitudes, the power of the students' responses is remarkable:

- . . . in England when you sneeze it comes out black . . .
- . . . when I heard my friend got skin cancer in high school . . .
- . . . some people do not care what has to be destroyed for them to achieve their goal . . .
- . . . witnessing the tremendous air pollution in Iran (people wear masks when they are outside) . . .
- . . . the experiment of that camping makes me know more about the environment . . .
- . . . I visited the Shenandoah valley and was awed by how serene nature is, how things go on despite all the problems we are aware of . . .

However, only one student made the connection that his or her program choice was motivated by environmental concern and was in itself a sign of having a caring attitude toward the environment. Thus, we wonder whether students' lived experiences could be used as a motivation for relevant courses.

It is interesting that more than 55% of the students surveyed did not name an environmental role model. It would be valuable to compare this response with another question, "Name the person whom you most respect as a role model," and also to compare the engineering students' responses with those of a group of similarly aged students in a different postsecondary program.

Of the 8 environmentalists mentioned more than once, Canadians were named 29 out of 33 times. People whom the students had certainly met were named 12 out of 33 times. The other 21 mentions were of people who are well-known media figures and may in addition have been people whom the students had actually met.

No student explicitly mentioned a family member or personal friend. It would be interesting to ask, "Whom among your family members or personal friends do you respect as an environmental role model, and why?"

Students' responses to the role model questions suggest some guidance for engineering professors trying to identify influential speakers or visitors to their environment-related programs. First, choose a Canadian (when in Canada). Second, it should be someone with a high profile in the media. Third, do not underestimate the value of the role modeling provided by the program faculty members.

The students' responses raise an issue related to "big-stage" and "small-stage" environmental advocacy. When these students graduate and start practicing engineering, the engineering advocacy to which their profession calls them is likely to take place in individual or small-group meetings with clients or colleagues. Their role will include having a value structure, an overview of environmental issues, and specific up-to-date, job-related information to support their case-by-case environmental advocacy as the opportunity and need arise. That is small-stage advocacy. It requires different skills from big-stage advocacy: the media personality who makes a television program about a single environmental issue, the professor who prepares a lecture, the author who writes a book for the general public. Big-stage advocacy in a media personality may be inspiring, whereas in a colleague it could just be annoying. We are primarily teaching engineering students to be colleagues. How can we help them identify and model themselves on effective small-stage environmental advocates?

Conclusions

The interpretation of the forced-answer results indicates several trends:

1. Students' technical knowledge of basic principles in environmental engineering and water resources engineering improved over the 18 months of the study.
2. Students' responses to more subtle technical questions were mixed but generally showed change toward instructors' aspirations.
3. Answers to attitudinal questions generally exhibited a trend toward increased environmental awareness.

Although students' answers to technical and attitudinal questions did exhibit significant changes over the study period, none of the changes could really be described as dramatic. The instructors postulated that the changes seemed somewhat analogous to a Bayesian updating process. The students did synthesize new knowledge over the 18 months of study, but their prior knowledge, tested on the pretest, was still discernible in the posterior posttest results.

A challenging question is whether or not the observed attitudinal changes can be attributed to material taught in courses (including instructors' attitudes) or to factors outside of the lecture room, such as students' exposure to the media. For example, problems of water pollution, smog, urban sprawl, and waste disposal have been well publicized in the greater Toronto area in recent years. However, whether influences inside and outside the lecture room can be truly separated is debatable; they are perhaps more likely to reinforce one another. Some insight into these questions may be gained as students in subsequent years complete the survey.

Several conclusions can also be drawn from the open-ended questions:

1. Students' increased technical knowledge of engineering influenced their perceptions of what practicing engineers do. The ratio of means-to-ends-related practices increased from 1.67 on the pretest to 5.32 on the posttest.
2. Students' perceptions of their own attitudes toward the environment did not significantly change over the period of study. However, there was some maturing in the behaviors mentioned as proof of caring; on the posttest, an increased percentage of students mentioned involvement in advocacy or awareness of environmental issues.
3. Air pollution and solid waste were most commonly mentioned as issues that influenced students' attitudes toward the environment. With respect to both these issues and others mentioned, the students were seemingly more influenced by local environmental issues; broader environmental concerns such as ozone depletion and global climate change had little impact. University courses were seen as a growing source of information on the environment over the 18-month period.
4. Students were generally found to be lacking environmental role models. Only around 40% of

students were able to name an environmentalist whom they respected as a role model. Canadian environmental advocate David Suzuki was most commonly mentioned, followed by several of the students' professors.

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Christopher Kennedy is an assistant professor in civil engineering at the University of Toronto, where he teaches courses in hydrology, hydraulics, and groundwater. His research interests include sustainable urban infrastructure.

Rosamund Hyde is a sustainable buildings researcher and LEED accredited professional with Keen Engineering Co. Ltd. in Vancouver, British Columbia. She obtained her Ph.D. in civil engineering from the University of Toronto with a dissertation on educating engineers for environmentally sensitive practice.

Bryan 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. The larger issue of educating for environmental sensitivity is a long-term passion. He received the Faculty of Applied Science and Engineering Distinguished Teacher Award in 2002.