AC 2010-662: ENGAGEMENT WITH ETHICS IN A LARGE ENGINEERING PROGRAM: A STATUS REPORT

Steven Culver, Virginia Tech

Steve Culver is the Associate Director of the Office of Academic Assessment at Virginia Tech. He is involved in evaluation activities across the university and has been an evaluation consultant to such diverse organizations as the Education Ministry of Finland, the National Community College Center for Cooperative Education, Eastern Mennonite College (VA), the Junior Engineering Technical Society, the West Virginia Department of Education, the United States Department of Education, and the State Council for Higher Education in Virginia. As a part of his current job responsibilities, Dr. Culver conducts focus groups and surveys campus-wide and provides in-depth analyses of those projects to multiple audiences.

Vinod Lohani, Virginia Tech

Vinod K Lohani is an associate professor in the Engineering Education Department (EngE) and an adjunct faculty in the Civil and Environmental Engineering at Virginia Tech. He received a PhD in civil engineering from Virginia Tech in 1995. His research interests are in the areas of knowledge modeling, water and energy sustainability, engineering learning modules for freshmen, and international collaboration. He led a major curriculum reform project (2004-09), funded under the department-level reform program of the NSF, at Virginia Tech. A spiral curriculum approach is adopted to reformulate engineering curriculum in bioprocess engineering in this project. He co-authored an award winning paper with his student Dr. Jennifer Mullin, first PhD graduate in EngE, and others at the 2007 annual conference of ASEE. He received the College of Engineering (CoE) Faculty Fellow award in 2008 and is selected to receive the W.S. 'Pete' White Innovation in Engineering Education Award in 2010 from the CoE.

Ishwar Puri, Virginia Tech

Ishwar K. Puri is Professor and Department Head of Engineering Science and Mechanics (ESM) at Virginia Tech. He obtained his Ph.D. (1987), and M.S. (1984) degrees in Engineering Science (Applied Mechanics) from the University of California, San Diego after obtaining a B.Sc. (1982) in Mechanical Engineering from the University of Delhi. He joined the University of Illinois at Chicago (UIC) in 1990 as an Assistant Professor in its Mechanical Engineering Department before moving to Virginia Tech in 2004. Puri is a Fellow of the American Society of Mechanical Engineers (ASME) and of the American Association for the Advancement of Science (AAAS).

Engagement with Ethics in a Large Engineering Program: A Status Report

Introduction

Virginia Tech offers one of the largest engineering programs in the country. As per ABET criterion 3f, an engineering graduate should demonstrate an understanding of professional and ethical responsibility. However, specific guidelines to achieve this objective are not provided. Engineering freshmen at Virginia Tech are introduced to professional ethics using in-class discussion of ethics case studies, ethics videos, reading and writing assignments, and online instructional materials. However, coverage of ethics instruction in upper level courses has not been documented or assessed. An interdisciplinary faculty group received an NSF grant in 2008 to enhance ethics instruction in undergraduate and graduate engineering curricula, and they have taken a number of steps to achieve this objective. This paper has two main objectives: (i) review the status of ethics instruction at Virginia Tech's large engineering program and suggest a framework to cover ethics instruction throughout the curriculum, and (ii) discuss results of a college-wide survey administered to gauge the perceptions of undergraduate and graduate engineering students regarding their current ethics instruction.

The Need for Ethics Instruction in Engineering

There have been numerous calls for improved instruction in ethics in engineering over the last several years, especially given the pace of technological advances and accompanying consequences. Typically these calls focus on more broad training in ethics, rather than micro-ethical problem solving [1]. Suggestions also include a wide range of solutions, including faculty development programs for ethics instruction [1a], required social sciences coursework [2], and the incorporation of an open ethics dialogue within engineering courses [3]. It has been suggested to consider professional codes of ethics in engineering as a useful framework for thinking about the student learning outcomes in the area of ethics and professional responsibility [4]. Service learning has been proposed as the learning pedagogy for effectively teaching professional skills and need to continue research is the area of assessment of professional skills is emphasized [5]. In a recent article, ethics instructions in engineering, health, business, and law professions are compared and it is observed that professionals in all disciplines continue to debate about the ethics instructional methods, curricular methods, and instructor qualifications with no clear-cut resolution [6]. Online ethics instruction modules have been suggested for graduate students, particularly from foreign countries, in engineering [7].

We have instituted several projects at Virginia Tech that provide a unique approach to instituting ethics education. The uniqueness derives from three particular characteristics: first, representatives from across the university are engaged as a collaborative team to help guide the process; second, the work builds on previous curricular work in the college; and third, a multi-dimensional evaluation was built into the process from the

very beginning as a way to evaluate the status quo and the eventual effects of changes in the curriculum related to ethics.

Interdisciplinary Ethics Education Project

In fall 2008, an interdisciplinary faculty group representing engineering, business, liberal arts and human sciences colleges, a university level research institute (*Institute for Critical Technologies and Applied Science*, ICTAS), and the academic assessment office at Virginia Tech received a 3-year grant titled "graduate interdisciplinary liberal engineering ethics (GILEE)" from NSF under the Ethics Education in Science and Engineering (EESE) program. These faculty members have been discussing ways to assess the current status of ethics instruction, particularly in engineering, and enhance undergraduate and graduate curricula by introducing ethics instruction at various levels.

In 2009, the group organized two key activities (an Ethics Day on March 18, 2009 and an Ethics workshop on June 8-9, 2009) at Virginia Tech which we believe are the first such activities on our campus. The Ethics Day activity included a panel discussion in which faculty members from engineering, philosophy, and science and technology studies shared their views on topics like "humanistic engineering," "ethics education – a philosopher's perspective," "engineering and social concerns," and "ethics in engineering education" with students and faculty. Another activity on Ethics Day was an invited seminar on "Collaboration on convergent technologies: trading zones, interactional expertise and moral imagination" that was delivered by a leading faculty expert from the University of Virginia. A large number of faculty and students attended this seminar. Following the success of the Ethics Day activities, the group organized a 1.5 day workshop on ethics in summer 2009. Approximately 25 participants, including graduate students and faculty members, from various engineering departments participated. Three faculty members from North Carolina A&T State University (NCA&T) also participated. The workshop was well received by the participants and workshop contents are available at: http://www.esm.vt.edu/~ikpuri/ethics/gilee.html. Seventeen participants responded to an eight-item workshop evaluation form and felt that they gained critical insight and appreciation into the field of ethics and became more aware of the value of integrating ethics throughout the curriculum. Several participants saw the workshop as a great way to start a broader conversation about ethics on campus and expressed interest in attending follow-up workshops.

From these activities and based on data gathered through the evaluation of these activities, the faculty group has developed a graduate course titled "Global and Ethical Impact of Emerging Technologies" that is being offered in spring 2010. The course is based on eight student outcomes derived from the previous work of the GILEE group. Upon successful completion of this course, students are able to:

- Analyze the influence of emerging technologies on contemporary life within and beyond the boundaries of the Unites States.
- Describe historical, technological, cultural, and scientific factors that influence the development of emerging technologies.

- Interpret and evaluate controversial issues of the day, such as stem cell research and the development of nanobiotechnologies, from several distinctive and differing ethical perspectives including egoism, utilitarianism, justice-based ethics, and rights-based ethics.
- Identify contemporary events at home and abroad related to the development of emerging technologies.
- Explain the crucial national and international role played by technology with respect to emerging technologies.
- Choose a critical basis for solving engineering problems in a globalized society.
- Articulate the difference between ethical relativism and ethical absolutism and their consequences.
- Explain the role of ethical thinking and action in relation to the development of emerging technologies, the related political contexts, the issue of sustainability and environmental stewardship, and the attendant social and economic changes.

The GILEE group continued the Ethics Day activity in 2010. This year a panel discussion was organized on March 03, 2010 and the highlight of this discussion was the presentations by students enrolled in above course sharing their perspectives on ethical dimension of emerging technologies. Some examples of presentation titles included: *Ethics in emerging technologies: the conflict with religion; How much information is too much information; Intersection of ethics and technology in education; Emerging technology ethics and geopolitics; Ethics and emerging technologies: the role of Engineers; and Ethics and sustainability education.* Another workshop is planned for summer 2010 and details are being discussed at the time of this writing.

Spiral Curriculum Work

The graduate course, discussed above, evolved, not only through the work of the GILEE group and its focus on ethics, but also as a natural evolution of previous curriculum work done in the college. As a part of a major NSF grant led by one of the authors [8], a spiral curriculum framework has been developed to reformulate engineering curriculum of the bio-process engineering which is a part of the Biological Systems Engineering department at Virginia Tech. The twentieth century psychologist, Jerome Bruner, proposed the concept of the spiral curriculum in his classic work *The Process of Education and The Culture of Education* [9] [10]. Bruner proposed that a learning curriculum could be arranged so that the central questions, or themes in a discipline, would be returned to again and again as learners advance in their knowledge and intellectual capacity. A 7-step process was used to implement the spiral curriculum in the bioprocess engineering and details are presented in [11] and [8]. One of the spiraling themes for this curriculum reformulation is ethics. As a result, ethics instruction was integrated throughout the bioprocess curriculum [12][13]. The participants at the summer 2009 workshop, discussed above, were introduced to the spiral curriculum theory and the spiral curriculum ethics work done in the bioprocess engineering department. Also, students in the graduate course, discussed above, have been assigned a semester project

to develop an ethics learning module and are suggested to consider the spiral curriculum approach for exploring instructional contents and strategies at different learning levels. Examples of students' modules will be presented at the time of presentation of this paper. Recommendations to weave ethics instruction throughout the curriculum have also been made in recent publications (e.g., [14]) and NSF workshop [15].

Ethics Instruction in College of Engineering (CoE)

Freshman Engineering Program

All engineering freshmen at CoE complete a 1-year long freshman engineering program before going into their engineering majors. In this program, freshmen are required to take a 2-credit engineering course (EngE1024) in fall semester. One of the learning objectives of this course is to demonstrate an understanding of professional ethics and application to real-life situations upon successful completion of the course. Students are assigned textbook readings on ethical theories, ethics case studies and videos (for example, *Incident at Morales and Gilbane Gold*) and are engaged in in-class discussion of ethics scenarios published in various professional publications. Ethics skits and discussion of contemporary issues like Hurricane Katrina have also been included in ethics instruction [16][17]. In addition, since fall 2007, hundreds of freshmen have used a web-based engineering ethics environment as part of an NSF-sponsored research project. This project, in collaboration with an education psychologist from the University of Missouri, explored ways that would encourage knowledge transfer and improve ethical problem solving [18].

Since fall 2006, a TabletPC-enhanced pedagogy has also been introduced in the freshman engineering program. All freshmen are required to own a Tablet PC. A classroom interaction software DyKnow is used with Tablets to develop a feedback back instruction in large classrooms [19]. Effectiveness of TabletPC/DyKnow-based instruction is documented in [20]. These technologies have also been employed to facilitate in-class discussion on ethics topics. For example, students were presented with the ABET criterion 3f "An understanding of professional and ethical responsibility" and were asked to write their thoughts by answering the question: "What does above statement mean to you?" Though this technology, their responses were collected immediately and projected to the entire class. Students could then, as a group, discuss responses that ranged from "*knowing the right thing to do*," to "*knowing what actions as an engineer are morally justified*," to "*respect cultural values and decide accordingly*."

Another example of an in-class ethics exercise is discussion of a case study summarized from a newsletter published by the American Society of Civil Engineers (ASCE)[21]. The case study is presented below.

> *"Florin prepares professional reports that include design parameters for structural foundations. To write these reports, data collected by his company's drilling team and geologists are needed. Sometimes, Florin makes site visits when the drilling team is scheduled to be there so he can check the data. Florin meets Downholt at a site where an office complex is to be constructed. While on*

site, Florin notices no one is taking borings; Downholt explains that the borings were taken on the previous day. However, in the snow, Florin sees no evidence that the borings were done. Florin worries that the borings data is inaccurate. Perhaps the drilling crew took borings at the wrong place? The accuracy of the borings critically affects the design recommendations for his report. The report is due in six days."

Students were given a minute to read the story and then were presented with following options about what Florin should do:

a) *Boring logs from nearby sites are probably okay to use since soil conditions in the area do not vary significantly.*
b) *Florin should call the geologist and get proof that the existing data came from borings at the site. If proof is unavailable, the boring crew should be fired.*
c) *Florin should tell the client his concerns and ask for an extension to finish the report.*
d) *Florin should tell the client that more samples are needed to complete the report because initial data is inconclusive. Florin should hire another crew to take borings at the site.*
e) *Florin should demand that the geologist and drilling crew return to the site over the weekend and give him samples on Monday.*
f) *After getting correct data from the geologist and drillers, Florin should have Downholt fire the geologist and drillers since they cannot be trusted. Florin should tell Downholt that he will be fired in the future if a similar incident occurs.*

Students were, first, asked to vote on an individual basis to pick one of the above options. Again, their votes were recorded using Tablet and DyKnow technologies. After individual voting, students were asked to get together with one of their neighbors and discuss the same case study again and vote again based on their discussion with a neighbor. Figure 1 shows results of individual and group thinking votes in spring 09 and fall 09 semesters. The six answer options are plotted along the x-axis (N/A indicates invalid response). It is clear that students do change their minds after talking to their peers and these results are shared back with students to make this point that ethics is like a design issue with multiple answers. Students are then informed about the choices professionals made at the ASCE conference (i.e., choices b & e). Students again understand the importance of examining an ethical scenario from multiple perspectives. Students were also asked to indicate their preference to learn ethics. Here're the results.

What will you prefer? (spring 09, N=164) (fall 09, N=134)

a. *A course in my major solely dedicated to engineering and professional ethics [11%] [10%]*
b. *Ethics modules in each engineering class throughout four years* ***[30%] [37%]***
c. *A required course on moral theory from Philosophy department [7%] [13%]*
d. *I can learn professional ethics on my own [18%] [11%]*
e. *Ethics can't be taught [24%] [9%]*
f. *Invalid [10%] [10%]*

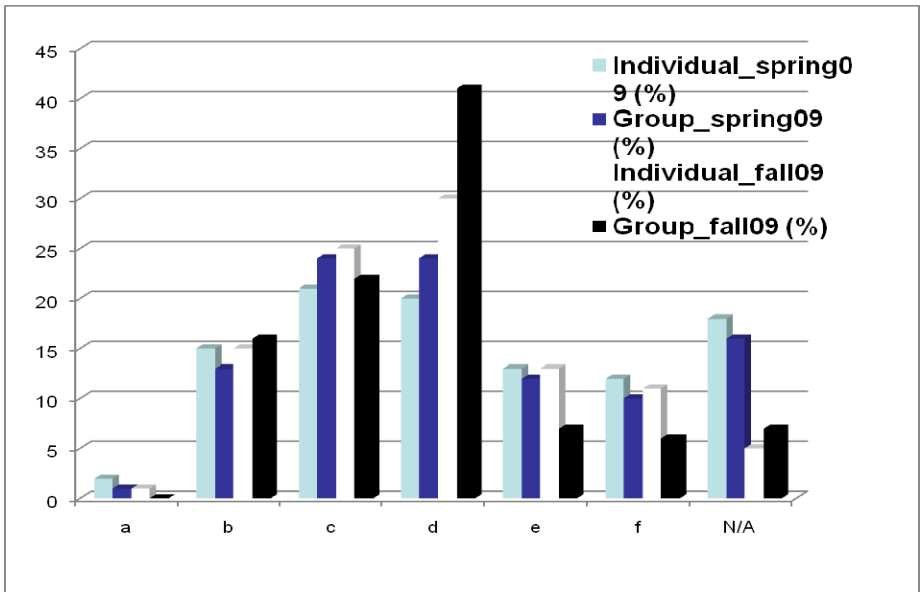

Figure 1: Results on individual and group thinking votes on ethics case study
(spring 09, n = 164; fall 09, n=134)

It can be seen that majority of students would like to have an ethics module in each engineering class throughout four years. Freshmen in EngE1024 complete an exit survey to assess the effectiveness of the course. Figure 2 shows response to an exit survey question related to ethics instruction.

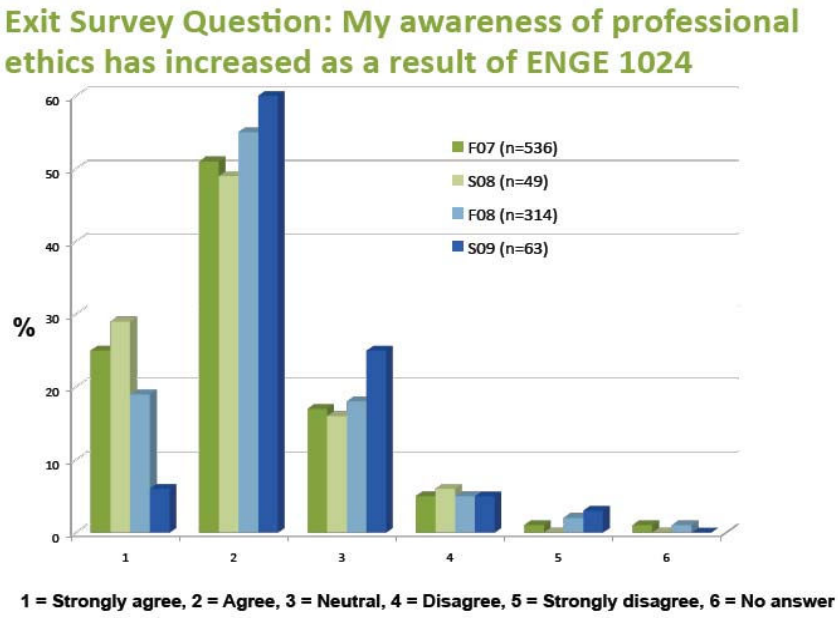

Figure 2: Exit Survey Response Summary – Ethics instruction in freshman year

Ethics instruction in Engineering Departments

In order to understand the current coverage of ethics in various engineering programs, a short survey was given to Assistant Department Heads, on March 4, 2009, who are typically responsible for undergraduate curriculum. The questions and a summary of responses obtained are given below.

Q1: In your undergraduate curriculum (sophomore year onwards), do some courses cover engineering ethics? If yes, can you briefly explain? (Example: name of courses, ethics modules developed, contact persons, etc.)

Seven responses: CEE (1), ChE (2), CS(2), ISE (3), Mining (3), ME(3), MSE(1)

CEE (1) means one course in civil and environmental engineering program includes ethics module as per CEE's Assistant Department Head

Q2: If your students do a senior design project, is there an ethics component in this project?

[Seven responses] Yes (4) No (3)

Q3: Do you think ethics should be integrated across the curriculum? If yes, do you have any suggestions? What're the impediments?

[Six responses] Yes (5) No (1)

Impediments: Resistance to replacing technical content, What to cut out?
How should faculty teach it? How are they "qualified" to teach ethical issues?
How do we assess students' knowledge in this area? Unclear, how to do this effectively? Faculty reluctant to impose ethical judgments in the class

It is apparent from this survey that ethics instruction in not widespread in the CoE. In order to formally assess the status of ethics instruction in both graduate and undergraduate curricula, a survey instrument was developed and implemented in the entire CoE for the first time. Next section presents the details.

Survey Instrument for Assessing Ethics Instruction in CoE

To provide one measure of current ethical practices in the curriculum and students' attitudes and knowledge regarding ethical concepts, we attempted to design a two-part survey, with acceptable psychometric properties, that could be administered electronically to large groups of students. This information provides both a baseline and valuable guidance for future curricular changes and approaches.

Instrument development

Development of the instrument was based on two distinct purposes: (1) an assessment of student perceptions of ethics training in the curriculum and (2) students' perceptions of key ethical issues, framed by key concepts in the literature: global differences, advocacy, ethical leadership, emerging technologies, and ethical relativism/absolutism. Item pools were generated for each of the two sections by an interdisciplinary group of engineering faculty, assessment professionals, and survey practitioners. For part one, 11 items to assess student perceptions of the level of ethical training in their curriculum were created. For each of these statements, students were asked to indicate their level of agreement using a six-point Likert scale: (1) Strongly Disagree, (2) Disagree, (3) Slightly Disagree, (4), Slightly Agree, (5) Agree, and (6) Strongly Agree. Sample items included "In my

engineering curriculum, there has been a substantial emphasis on teaching ethics;" "the textbooks and course materials I have used in my engineering curriculum often cover ethical issues;" "many examples of the relationship between emerging technologies, such as nanotechnology and biotechnology, and ethics have been discussed in my engineering curriculum."

For part two, 11 items designed to assess student perceptions of key ethical issues framed by key concepts in the literature were created. As in part one, for each of these statements, students were asked to indicate their level of agreement using a six-point Likert scale: (1) Strongly Disagree, (2) Disagree, (3) Slightly Disagree, (4), Slightly Agree, (5) Agree, and (6) Strongly Agree. Sample items in this section included "in general, ethics is independent of the country or culture in which it occurs:" "if a professional practice is legal, then it is also necessarily ethical:" "ethics is too complicated and cannot be taught:" "professional ethics and personal ethics are two separate things."

Results from the survey

After approval from the university's IRB, an email was sent to all undergraduate and graduate engineering students at Virginia Tech through the engineering listserve to which all engineering students have access and where they typically receive announcements regarding events, registration, course changes, etc. The email contained a brief overview of the purpose of the survey, asking for their response and assistance. The email contained the link for the web-based survey. No identifying information related to individuals was collected, though demographic items on the survey included age, gender, level of study (freshman, sophomore, junior, senior, master's, doctoral), primary area of engineering (e.g., aerospace, biological systems, chemical, etc.).

A sample of 563 engineering students responded to the survey, of those 437 (78%) were undergraduates and 126 (22%) were graduate students. All years of study were included in the sample with 117 (21%) Freshmen, 97 (17%) Sophomores, 84 (15%) Juniors, 138 (25%) Seniors, 58 (10%) Master's students, and 67 (12%) Doctoral students. Ages ranged from 18 to 57, with a mean age of 25.8 years. The sample consisted of 415 (74%) males and 148 (26%) females. Fifteen different engineering majors were represented, with Civil & Environmental Engineering having the most (21, 26%), followed by Industrial & Systems Engineering (17, 14%), and Electrical Engineering (15, 12%). Frequency of responses and means and standard deviations for each item on the first part of the survey are presented in Table 1.

Table 1: Student Perceptions of Teaching Ethics Scale (Part 1; 11 items, 6-point likert scale)

	Strongly Disagree	Disagree	Slightly Disagree	Slightly Agree	Agree	Strongly Agree	**Mean (SD)**
In my Engineering curriculum, there has been a substantial emphasis on teaching ethics.(#1)	22 (4%)	70 (13%)	65 (12%)	160 (29%)	181 (32%)	62 (11%)	**4.06 (1.32)**

I have been taught about an Engineer's core values and their relationship with effective ethical leadership. (#2)	15 (3%)	42 (8%)	54 (10%)	141 (25%)	231 (41%)	77 (14%)	**4.36 (1.21)**
The textbooks and course materials I have used in my Engineering curriculum often cover ethical issues. (#3)	35 (6%)	98 (18%)	93 (17%)	158 (28%)	137 (25%)	39 (7%)	**3.68 (1.36)**
My Engineering curriculum has informed me of the many ways in which professionals can become effective advocates for ethically relevant decisions and legislation. (#4)	43 (8%)	102 (18%)	93 (17%)	146 (26%)	143 (26%)	32 (6%)	**3.61 (1.39)**
In my Engineering curriculum, the professors have avoided discussions of difficult ethical issues. (#5)	38 (7%)	196 (35%)	149 (27%)	92 (17%)	59 (11%)	20 (4%)	**3.00 (1.24)**
In my Engineering curriculum, an international perspective in ethics has been discussed. (#6)	68 (12%)	145 (26%)	115 (21%)	118 (21%)	81 (15%)	26 (5%)	**3.14 (1.40)**
In my engineering curriculum, I have often had the opportunity to initiate discussions regarding ethical issues. (#7)	63 (11%)	149 (27%)	130 (23%)	123 (22%)	79 (14%)	13 (2%)	**3.08 (1.31)**
Many examples of the relationship between emerging technologies, such as nanotechnology and biotechnology, and ethics have been discussed in my Engineering curriculum. (#8)	95 (17%)	158 (28%)	114 (20%)	104 (19%)	73 (13%)	16 (3%)	**2.91 (1.39)**
In my engineering curriculum, I have been taught the differences between ethical relativism and ethical absolutism. (#9)	154 (28%)	150 (27%)	90 (16%)	87 (16%)	64 (12%)	12 (2%)	**2.63 (1.43)**

In my Engineering curriculum, the professors demonstrate a great deal of knowledge regarding ethical issues. (#10)	29 (5%)	70 (13%)	97 (18%)	173 (31%)	148 (27%)	34 (6%)	**3.80 (1.28)**
In my Engineering curriculum, the professors have often expressed concern over ethical issues in applied settings. (#11)	30 (5%)	93 (17%)	116 (21%)	150 (27%)	132 (24%)	37 (7%)	**3.67 (1.32)**

As can be seen in Table 1, students are more likely to agree that they have been taught about an engineer's core values and their relationship with ethical leadership (#2) and that there has been a substantial emphasis on teaching ethics in the curriculum (#1). However, they are less likely to agree that they have been taught the differences between ethical relativism and absolutism (#9) or that emerging technologies, such as nanotechnology and biotechnology, and ethics have been discussed (#8). In short, students seem to perceive in a general way that they have received ethics instruction but yet, when faced with specific aspects of that instruction, their perceptions are less positive.

Table 2 presents students' responses to the second section of the survey which focuses on students' perceptions of ethics rather than their perceptions of their ethics instruction.

Table 2: Student Perceptions of Ethics in Engineering Scale (Part 2; 11 items, 6-point scale)

	Strongly Disagree	Disagree	Slightly Disagree	Slightly Agree	Agree	Strongly Agree	**Mean (SD)**
Ethics in engineering is accepted as the same across cultures and nations. (#12)	69 (13%)	187 (34%)	92 (17%)	104 (19%)	71 (13%)	24 (4%)	**2.99 (1.40)**
Ethical concerns for emerging technologies such as nanotechnology and biotechnology do not apply to most of us because science is separate from	184 (34%)	234 (41%)	68 (13%)	31 (6%)	25 (5%)	3 (.6%)	**2.06 (1.09)**

society.(#13)							
If a professional practice is legal, then it is also necessarily ethical.(#14)	167 (31%)	207 (38%)	72 (13%)	46 (8%)	39 (7%)	14 (3%)	**2.31 (1.32)**
In general, ethics is independent of the country or culture in which it occurs.(#15)	68 (13%)	152 (28%)	97 (18%)	89 (16%)	109 (20%)	29 (5%)	**3.19 (1.48)**
Active advocacy on the part of an Engineer has no potential to influence legislation.(#16)	101 (19%)	239 (44%)	127 (24%)	49 (9%)	19 (4%)	6 (1%)	**2.38 (1.07)**
Ethical leadership is not a concern in Engineering.(#17)	218 (40%)	226 (42%)	61 (11%)	22 (4%)	16 (3%)	2 (.4%)	**1.90 (.99)**
Ethics is too complicated and cannot be taught.(#18)	196 (36%)	190 (35%)	89 (17%)	35 (7%)	24 (4%)	6 (1%)	**2.11 (1.16)**
Professional ethics and personal ethics are two separate things.(#19)	83 (15%)	111 (21%)	110 (20%)	119 (22%)	95 (18%)	24 (4%)	**3.19 (1.45)**
Ethics do not vary from situation to situation.(#20)	78 (14%)	176 (33%)	123 (23%)	64 (12%)	72 (13%)	27 (5%)	**2.92 (1.42)**
Ethical issues do not pertain to technological advances.(#21)	189 (35%)	251 (46%)	54 (10%)	23 (4%)	18 (3%)	7 (1%)	**1.99 (1.06)**
In general, the accepted practices of cultures in other countries determine what is ethical. (#22)	56 (10%)	132 (25%)	110 (20%)	158 (29%)	72 (13%)	11 (2%)	**2.11 (1.16)**

As seen in Table 2, students' responses demonstrate their inconsistent views regarding ethics and the profession. For example, students are more likely to agree that professional ethics and personal ethics are two separate things (#19) and they tend to feel that ethics is independent of the country or culture in which it occurs (#15). However, they are less likely to agree that, if a professional practice is legal, then it is also necessarily ethical (#14). They also disagree that ethical concerns for emerging technologies do not apply to most of us because science is separate from society (#13). They also disagree with the statement that ethics is too complicated and cannot be taught (#18).

Factor analysis. Because the two sections of the survey were theoretical derived to be one scale for perceptions of ethical training in the curriculum and one scale for perceptions related to ethics generally, a factor analysis was conducted to determine if these scales could be derived and were reliable indicators. For part one of the instrument, initial exploratory factor analysis (EFA) using maximum likelihood estimation resulted in the retention of a two-factor structure explaining a total of 63.35% of the total variance in the data. Upon inspection of the factor structure, however, we found one item with a factor score below .40 and a factor correlation of .71 indicating one bad item as well as highly correlated factors. We removed the item and conducted a second EFA, extracting a one factor solution explaining 52.1% of the total variance. The ten-items retained constituted an initial scale assessing student perceptions of ethics training in their curriculum, or Curricular Ethics (CE). The CE scale also demonstrated a high degree of internal stability ($\alpha = .91$), with item inter-correlations ranging from .40 to .75.

Of particular interest are results related to subgroups on part one of the survey. For instance, when comparing the scale scores of undergraduates with graduate students, the undergraduates have higher scores; in fact, the freshmen have the highest average score, with sophomores second, with juniors third, in a consistent pattern such that doctoral students have the lowest average scores. Consequently, students earlier in their programs seem to perceive they have better coverage of ethics in the curriculum than students later in their programs. Perhaps most disheartening is that the graduate students, the future professoriate, seem to believe they have the least ethics coverage and training in their curriculum.

For part two of the instrument, initial exploratory factor analysis using maximum likelihood estimation resulted in a two-factor structure explaining 50.6% of the total variance. Upon inspection of the factor matrix, it was noted that two items had factor loading under .40. One by one, we removed those items and ran another EFA each time. The final structure consisted of two highly correlated factors ($r = .72$) accounting for 57.1% of the total variance. Item and reliability analysis of the two scales resulted in an even more muddled picture of the part two assessment. Three items made up the first scale, with no theoretical ties between them to identify the content of the scale. In fact, the scale consisted of items designed to assess student perceptions of global differences, advocacy, emerging technologies. Indeed, the scale demonstrated poor internal

consistency (α = .67). Only if one of the three items were deleted did the scale reliability improve, still it did not demonstrated a high degree of internal stability (α = .71).
Six items made up the second scale and again no theoretical ties were found to identify the content of the scale. Internal consistency, however, was acceptable (α = .77). Further inspection of the scale indicated that some items introduced unreliability into the scale and that internal consistency could be improved if removed. After all unreliable items were removed, the scale shrunk to four items with an acceptable degree of internal consistency (α = .81). Again, the content of the items in this scale were not theoretically similar. The scale consisted of items designed to tap four different dimensions of ethics; advocacy, ethical leadership, emerging technologies, and ethical relativism/absolutism. Although this scale demonstrates acceptable internal stability, the content of the scale is theoretically unclear. Consequently, part two of our developed instrument did not lend itself to the creation of single-scale scores as was the case with part one of the survey.

The goal of the current study was to create an initial assessment of student perceptions of ethics training within their curriculum as well their perceptions related to five key ethical issues in the literature. From the item and scale analysis, it appears that we have initial validation and reliability evidence for the CE scale. However, the items intended to assess five ethical dimensions did not yield theoretically consistent factors and generally demonstrated a high level of unreliability.

Focus groups

As part of the study design, follow up focus groups were conducted to examine more fully student responses to the survey in an attempt to further validate the instrument and to suggest revisions (especially in part two of the instrument). The first focus group was conducted in a graduate engineering education class of 3 women and 4 men, with backgrounds across several of the engineering majors. Students were provided with seven of the questions from the survey and asked for their perceptions of how students had responded on the survey and how that matched your own experiences. The results of this focus group suggest that, at least with this group, engineering students are unfamiliar with ethical issues other than those raised in case studies specific to their specialization. A "silo effect" was noticeable in this group as the approach to ethics was determined by students' experiences in their particular engineering major. It seemed that little discussion regarding ethics across engineering majors or use of common ethics scenarios were used. The students' lack of familiarity with ethical terms could be one reason for low reliability for responses to part two of the survey.

A second focus group conducted in a graduate engineering class in industrial and systems engineering major at NCA&T (where the survey was not administered) followed the same format. Results of this focus group again suggested that engineering students lack facility regarding discussion of ethical issues. For example, one student noted that ethics is covered in every class because the instructor talks about the university's honor code on the first day. Also, students tended to confuse items intended to assess ethics perceptions with judgments of morality or professionalism. In short, it may be difficult for some items on a survey to gauge certain aspects of students' knowledge or perceptions reliably and with a certain validity if the students lack familiarity with the topic.

Implications

The results of our evaluation activities suggest that this sample of engineering students did not possess a familiarity with terms related to ethical decision-making and were unclear about what exactly "ethics" is. While students are comfortable talking about an ethical situation that is presented as an ethical scenario in a textbook, they are less able to discuss elements of ethical frameworks such as "absolutism," "moral responsibility," or "cultural differences" related to ethics. These findings suggest that the use of such typical instruments as the Defining Issues Test (DIT), developed by James Rest [22], or the Socio-moral Reflection Measure (SRM), based on Kohlberg's work [23], may lead to results that provide only a surface view of students' ethical knowledge and decision-making.

These findings also suggest that assessment of student knowledge and abilities is a task filled with complexities, but the process is even more difficult for evaluating ethical decision-making. Overlapping areas of knowledge related to the engineering profession, to cultural knowledge, to critical thinking, and to language abilities, all provide complexity to such measurements. Multiple methods, including quantitative and qualitative methodologies, used longitudinally over time, may provide for a collection of evidence that can help us draw a better picture of what our students can and cannot do.

Summary

This paper summarizes the efforts of an interdisciplinary group of faculty working to enhance ethics instruction in graduate and undergraduate curricula at Virginia Tech. They are using a spiral curriculum framework to weave ethics instruction throughout the curriculum. Both students and faculty support this approach of ethics instruction. A graduate course on "Global and Ethical Impact of Emerging Technologies" has been developed and is being offered in spring 2010. Students in this course are assigned to develop an ethics learning module to discuss ethical implications of their research. The authors have conducted a college-wide ethics instruction survey for the first time and results suggest that students accurately report the training they receive in their engineering curriculum regarding ethics. Most believe, for instance, that "there has been a substantial emphasis on teaching ethics" in the curriculum, yet there are few that agree with the idea that "many examples of the relationship between emerging technologies, such as nanotechnology and biotechnology, and ethics have been discussed" in their curriculum or that they "have been taught the differences between ethical relativism and ethical absolutism." Ten items on this survey provide a scaled measure of students' perceptions of ethics teaching in their curriculum. However, students' knowledge regarding aspects of ethics is more difficult to ascertain, in part because engineering students may lack the language and perspectives to discuss aspects of ethics and the ramifications stemming from choices that are made in ethical dilemmas.

Acknowledgement

This material is based upon work supported by the National Science Foundation under Grant No.(NSF/EESE#0832852). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

Bibliography

[1] Herkert, J. R. (2000). Engineering education in the USA: Content, pedagogy, and curriculum. *European Journal of Engineering Education*, 25(4), pp. 303-313.

[1a] Herkert, J. R. (2002). Continuing and emerging issues in engineering education. *The Bridge*, 32(3).

[2] Vesilind, P. A., (2001). Engineering as Applied Social Science, *Journal of Professional Issues in Engineering Education and Practice*, Vol. 127, No. 4, October 2001, pp. 184-188,

[3] Winkelman, P., (2006). Integrating Open-Ended Design in a Science and Mathematics Based Engineering Program, available at: http://cden2006.utoronto.ca/data/10057.pdf (accessed: March 28, 2010).

[4] Colby, A. and Sulliman, W. M., (2008). Ethics Teaching in Undergraduate Engineering Education, *Journal of Engineering Education*, vol. 97, no. 3, pp. 327-338.

[5] Shuman, L. J., Besterfiled-Sacre, M., and McGourty, J., (2005). The ABET "Professional Skills" – Can They Be Taught? Can they be assessed? *Journal of Engineering Education*, vol. 94, no. 1, pp. 41-55.

[6] Barry, B. E. and Ohland, M. W., (2009). Applied Ethics in the Engineering, Health, Business, and Law Professions: A Comparison, *Journal of Engineering Education*, vol. 98, no. 4, pp. 377-388.

[7] Lawson, W. D., Newberry, B. P., Matzner, M., and Austin, K. A., (2010). Designing Online Ethics Instruction Modules for Graduate Engineering Students, Workshop Handout, *NSF Engineering Education Awardees Conference*, Jan. 31- Feb. 02, 2010, Reston, VA.

[8] Lohani, V. K., Wolfe, M. L., Wildman, T., Mallikarjunan, K., and Connor, J., (2010). *Reformulating General Engineering and Biological Systems Engineering Programs at Virginia Tech*, Submitted to the *Advances in Engineering Education* Journal in August 2009.

[9] Bruner, J. (1960). *The process of education*. Cambridge, MA, Harvard University Press.

[10] Bruner, J. (1996). *The culture of education*. Cambridge, MA, Harvard University Press.

[11] Wolfe, M.L., T. Wildman, K. Mallikarjunan, V.K. Lohani, and J. Connor. (2009). Spiral Curriculum to Facilitate Student Learning and Development, In: Roy, R. (Editor). *Engineering Education: Perspectives, Issues and Concerns*, Delhi, India: Shipra Publications. pp. 419-436.

[12] Whysong, C.Y., Lo, J., and Mallikarjunan, P. (2007). Improving Ethics Studies through a Spiral Themed Curriculum: Implementing Ethics Discussion at the Sophomore Level. Proceedings of the *2007 ASEE Annual Conference and Exposition*, Honolulu, Hawaii, June 24-27, 2007, 13 pages.

[13] Mallikarjunan, P. , Whysong, C.Y., and Lo, J., (2008). Improving Ethics Studies through a Spiral Themed Curriculum: Piloting an Ethics Discussion at the Senior Level. Proceedings of the *2008 ASEE Annual Conference and Exposition*, June 22-25, 2008, Pittsburgh, 15 pages.

[14] Sheppard, S. D., Macatangay, K., Colby, A., and Sullivan, W. M., (2009). Educating Engineers – Designing for the Future of the Field, Jossey-Bass, San Francisco.

[15] Harding, T.S., Carpenter, D J., and Finelli, C. J., Ethics in Engineering Curricula, 2009 *NSF Awardees Conference*, 1-3 Feb., 2009, Reston, VA.

[16] Mullin, J.S., Lohani, V.K., and Lo, J.L., (2006). WIP: Introduction to Engineering Ethics through Student Skits in the Freshman Engineering Program at Virginia Tech, Proceedings of the *2006 Frontiers in Education Conference*, San Diego, CA, October 27- November 1, 2006.

[17] Lo, J.L., Lohani, V.K., and Mullin, J.S., (2006). Student Presentations on Contemporary Engineering Ethics Issues in an Introductory Freshman Engineering Course, Proc. *2006 Annual Meeting and Conference of the American Society for Engineering Education*, Chicago, IL, June 18-21, 2006.

[18] Jonassen, D., Shen, D., Marra, R., Cho, Y., Lo, J., and Lohani, V. K., (2009). Engaging and Supporting Problem Solving in Engineering Ethics, *Journal of Engineering Education*, ASEE, vol. 98, no. 3, pp. 235-254.

[19] Lohani, V.K., Castles, R., Lo, J., and Griffin, H., (2008). Tablet PC Applications in a Large Engineering Program, *Computers in Education Journal*, ASEE, vol. 3, pp. 52-63.

[20] Mokri, P. and Lohani,V. K., (2009). Investigating Changes in Students' Perceptions on Tablet PC Applications, Proc. *2009 WIPTE conference*, Oct. 12-13, 2009, Virginia Tech, Blacksburg.

[21] Lawson, W. D. and Brenner, B., A Question of Ethics: a case study, *ASCE News*, April 2007, p. 6.

[22] Self, D. J., & Ellison, E. M. (1998). Teaching engineering ethics: Assessment of its influence on moral reasoning skills. *Journal of Engineering Education*, 87(1), 29-34.

[23] Gibbs, J. C., Widaman, K. F., & Colby, A. (1982). Construction and validation of a simplified, group-administrable equivalent to the moral judgment interview. *Child Development*, 53(4), 895-910.