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Can Our Students Recognize and Resolve Ethical Dilemmas?*

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Abstract
ABET's accreditation criteria have provided additional impetus for preparing engineering graduates to understand their professional and ethical responsibilities. Accordingly, engineering ethics courses have stressed skills acquisition rather than behavior change. However, to date, methods to assess students' ability to resolve ethical dilemmas remain largely undeveloped. As part of a joint study at the University of Pittsburgh and the Colorado School of Mines, we are developing a measurement tool for assessing students' abilities to recognize and resolve ethical dilemmas. To date we have constructed and validated an analytic scoring rubric for ethical dilemmas consisting of five components: recognition of and framing the dilemma; use of information (both known and unknown, i.e., facts or concepts needed to resolve the problem but not included in the case text); analysis of the scenario; perspective taken; and suggested resolution. We have used the rubric to evaluate the capabilities of 120 students, ranging from freshman to graduate levels using a test consisting of three ethical dilemmas for which the student provides a written analysis. The analyses are then holistically scored using the rubric that allows us to classify the student's level of achievement. We present the results of these tests and discuss the lessons learned from this experiment. Our long-term objective is to develop a web-based assessment instrument similar to CSM's Cogito© system for assessing intellectual development that can be effectively used by engineering faculty to assess students' ability to recognize and resolve ethical dilemmas.

Introduction

Led by national commissions, industry leaders, and progressive educators [1-4], the Accreditation Board for Engineering and Technology (ABET) adopted its innovative Engineering Criteria 2000 in 1997 [5-6]. Today 1700 accredited programs have implemented continuous improvement systems that include individually defined objectives, outcomes, and an assessment process with the timely feedback of results. A minimum set of eleven outcomes covers both "hard" engineering skills; e.g., ability to design and conduct experiments; identify, formulate and solve problems; and use modern engineering tools, and such "professional" skills as the ability to work in multidisciplinary teams, communicate effectively, understand engineering in a global and societal context, recognize the need for life long learning, possess a knowledge of contemporary issues, and *understand professional and ethical responsibilities*, which is the focus of this paper.

Engineering educators have made considerable progress in assessing the "hard" skills, but assessment of the "professional" skills lags. In 2001, our research team from the University of Pittsburgh and the Colorado School of Mines received a NSF *Proof-of–Concept* award (DUE 01-27394) to demonstrate the feasibility of developing an engaging system for assessing the ability

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to recognize and resolve ethical dilemmas. In a former paper we described the process of developing and validating a scoring rubric [7] for assessing students. Here we provide additional data on the testing of a sample of 120 students' (freshman through graduate) ability to recognize and resolve ethical dilemmas.

Background

Until recently engineering educators focused primarily on providing students with technical skills and gave little priority to developing skills for societal decision-making, or even making students aware of the societal dimensions of engineering [8]. By 1999, only 27% of ABET accredited institutions listed an ethics-related course requirement [9], even though an increasing number of philosophers, engineers and ethicists were focusing their research and teaching on engineering ethics [10, 11]. Recently, practitioners' and the professional engineering societies' interest in engineering ethics has also increased with the IEEE being especially active [12, 13]. Now, with a number of exemplary models existing within the country's engineering schools, the need to incorporate ethics into the curriculum is no longer debated; e.g., see [14, 15]. Increasingly, educators have emphasized the important relationship between ethics and engineering design and the value of integrating the two within the curriculum [16-19].

However, if ABET's vision for understanding ethical and professional responsibilities is to become reality, educators now must determine: What is the appropriate content? Which pedagogy is preferable? Are some curriculum models better than others? Which works best---a required course, ethics-across-the-curriculum, integration of ethics with science, technology and society courses, or integration of the liberal arts into the engineering curriculum [20, 21]? And, which outcome assessment methods are most suitable [22, 23]?

Pfatteicher [24] has framed the educational 'dilemma' as how to provide meaningful ethics instruction to all students without overburdening faculty, increasing graduation requirements, or removing essential technical material from the curriculum. The ABET criteria call for ensuring that students *understanding* rather than *demonstrate* ethical knowledge; i.e., students should be evaluated on their knowledge and capabilities, not values and beliefs. Pfatteicher recommends that we provide students with an understanding of the nature of engineering ethics; the value of engineering ethics rather than the values of an ethical engineer; and the resolution of ethical dilemmas. To these we would add the ability to *resolve* those moral problems that arise in engineering practice.

What is missing is a way to assess the extent to which an engineering program's graduates can recognize and resolve complex, open-ended and often ill-defined ethical dilemmas, especially those that they may encounter in the routine practice of engineering. To do this, we have proposed adapting both the methodology for developing and validating the Cogito system (used for measuring intellectual development) [25-28] for assessing students' ability to recognize and resolve ethical dilemmas. We believe that there are a number of similarities between measuring intellectual development by presenting students with ill-defined, open-ended problems, and assessing students by presenting them with scenarios containing ethical dilemmas.

Measuring college students' intellectual development (ID) is a rich, sophisticated method for determining how well they are able to analyze and solve ill-defined, open-ended problems repre-

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sentative of the "real-world." Rather than measure the acquisition of specific knowledge and skills, assessments focus on the nature of knowledge and knowing, use of evidence to support complex decisions, dealing with trade-offs, and processes for solving open-ended problems. Progression towards higher levels of intellectual development can be used as evidence of professional expertise development. The most recognized and valid methods to quantify maturation of college students' intellectual abilities relies on developmental process models such as William Perry's Model of Intellectual and Ethical Development [29] and Patricia M. King and Karen S. Kitchener's Reflective Judgment (RJ) Model [30]. These models measure students' positions along a hierarchical construct of stages representing increasingly more sophisticated ways of understanding knowledge and solving complex, open-ended problems.

Perry developed his model from clinical studies of Harvard students in the 1960's. As he interviewed student groups at the end of each academic year, probing their views of their university experiences, he observed patterns of thinking that were hierarchical and chronological. He translated these patterns into a nine-stage model of development that he validated by a second, more extensive, longitudinal study. King and Kitchener developed the Reflective Judgment (RJ) model in the late 1970's from their graduate research on student intellectual development. They also used probing interviews of students as their primary data source and were able to identify hierarchical patterns of thought within those data. Each has spent decades since refining the model, gathering extensive reliability and validation data and teaching it to others. Their RJ model has seven stages--from a black/white dualistic view of knowledge through a relativistic ("all opinions equally valid") view to a multiplistic view in which alternatives are contextually analyzed using available knowledge and beliefs.

Both models require an hour-long interview, followed by transcription, and scoring by two trained experts. Hence, they are impractical for routine student or program assessment. To provide educators with a reliable, valid and inexpensive way to assess students' intellectual development, Miller, Olds and Pavelich developed the Cogito software system with support from FIPSE. Available in web-based and stand-alone versions, Cogito uses open-ended scenarios and an engaging graphic user interface to collect student response data which are scored by trained neural networks to estimate a student's ID as defined by the Perry and Reflective Judgment ID models.

The ID of approximately 300 college students and faculty has been measured with Cogito, with 88 subjects also sitting for ID interviews to collect data for training and testing the neural net scoring algorithms. Correlation coefficients relating ID level predicted by Cogito with interview measurements range from about 0.7-0.9, sufficient for aggregate program assessment measurements of groups of students over a long period; e.g., the duration of an undergraduate degree program. Measuring engineering students' ability to recognize and resolve ethical dilemmas is a cognitive task very similar to the open-ended problem solving activities assessed by Cogito. In fact, several scenarios used in intellectual development interviews and the Cogito software could be adapted as part of our current project.

The most widely recognized means of assessing moral ethical reasoning is based upon Kohlberg's comprehensive theory of moral development [31]. Rest expanded upon Kohlberg's work, proposing four sequential steps that must be taken to incorporate the ethical dimension in a deci-

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sion. Rest also developed the Defining Issues Test (DIT), a widely used instrument to determine a subject's moral development level based on Kohlberg's and his work [32, 33]. Staehr and Byrne recently used the DIT to evaluate computer ethics teaching, and found significant results for a very small sample of students [34]. Self and Ellison note that the DIT is reliable, valid, extensively supported by literature, efficient to use, and relatively low cost, especially when compared to other instruments [35]. The current version of the DIT (DIT-2) uses five dilemmas, none of which could be considered an engineering ethics scenario.

Kreie and Cronan [36-38] developed a survey instrument incorporating personal beliefs, societal and professional environment, personal attributes, legal environment, and business environment based on Bommer, et. al. [39]. Steneck proposed using four methodologies to assess the University of Michigan's ethics thread (direct measures of basic knowledge using standard testing techniques; evaluations of critical reasoning skills development using essay questions, responses on interactive case studies and other writing assignments; self-evaluations; and feedback from employer interviews) [40], although we did not find any reported results.

Ethical decision making (EDM) can be viewed as a special case of decision making. According to Miner and Petocz, it requires a cognitive activity (perceiving, knowing, believing, remembering, etc.) that is influenced by emotional and social pressures. EDM typically follows the same sequential phases as general decision making – problem recognition, identification of alternatives, evaluation of alternatives, selection and commitment. But, it also involves moral justification of the decision [41].

As part of our recent NSF-sponsored study of engineering education assessment [42], we developed a framework [43] for organizing each ABET outcome's possible attributes by adapting Bloom's general taxonomy based on six levels of the cognitive domain: knowledge, comprehension, application, analysis, synthesis, and evaluation [44]. A seventh affective domain - valuation - was added [45]. Outcome elements and associated attributes were then expanded within each of these levels. McBeath's action verbs for each level [46] were used to translate the attributes into learning outcomes in order to facilitate measurement. The specification of outcome 3.f. - *an understanding of professional and ethical responsibility* (based on the engineering ethics framework of Pinkus, Shuman, Hummon and Wolfe [47]) - also served to inform the rubric that we developed.

Proof of Concept Overview

We have shown that it is possible to develop a rubric to assess student responses that can be applied with relative consistency by raters and has face validity with ethics experts. The rubric can be used to assess students' comprehension, analysis, and resolution of ethical dilemmas in an engineering context. The development and application of this tool establishes the feasibility of assessing students' ability to understand ethical concepts. We have shown that it is possible to divide a cohort of students into levels that reflect their level of moral problem solving. Faculty can use this technique to inform curriculum enhancements. To date, we have completed the following:

Systems Definition: We hypothesized a model of the ethical engineering decision making process, initially utilizing the first three of four sequential levels proposed by Jones in his "model for

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ethical decision making": recognizing a moral issue, making a moral judgment, and establishing moral intent [48]. In doing this, we drew upon Pinkus, Chi, McQuaide and Pollack's experience gained in the cognitive study they conducted to understand how students learn ethics using a case-based reasoning approach [49]. This study was part of a larger initiative that developed PETE (Project Professional Ethics Tutoring Environment) a web-based tutoring program designed to help students read and analyze ethics cases in preparation for discussing them in class [49-51]. As mentioned previously, and Miller's and Olds' experience in developing the Cogito system were also used.

To identify measurable components for the various levels, we used the extensive attribute specification [52] for this outcome (ABET - 3.f) noted above. The attribute's seven levels were mapped into the rubric: knowledge and comprehension representing "recognition of a moral issue," application and analysis are "making a moral judgment," and synthesis and evaluation map into "establishing moral intent." (The attribute level valuation was not applicable here.) Satisfactory attainment of each level (in terms of its attributes) was defined to facilitate assessment; see [53].

Scenario Selection: We examined the eight ethical decision making scenarios constructed as part of the PETE project and the large number of cases available in the literature; e.g., Harris, Prichard and Rabin present over 200 cases [54]. We were particularly interested in cases that require what Harris, Prichard and Rabin refer to as "creative middle way solutions," where one must choose among two or more conflicting morally important values. Harris, et al provide a cognitive structure for approaching engineering ethics cases that helps students identify and integrate information relevant to the analysis, going from the case statement to relevant facts, factual issues, conceptual and application issues, moral issues and then analysis. At each step, one may iterate back to fill unresolved gaps. We used this method to analyze each scenario, since it is amenable to assessment by scoring rubrics and parallels an engineering approach to problem solving.

Four scenarios were selected for testing: *Artificial Heart* and *BioVis* written by Ferrari and Pinkus [55] and *Tools* and *Trees* originally prepared by Pritchard and colleagues under NSF funding [56]. *Artificial Heart* is based on the circumstances surrounding the first artificial heart transplant; *BioVis* is based on an FDA recall case. *Borrowed Tools* involves a young engineer observing his supervisor purchasing tools for his personal use; *Trees* deals with a highway engineer who must decide whether or not to cut down old growth trees (against the opposition of a group of environmentalists) in order to reduce the number of traffic accidents*.

Development of a Scoring Rubric: A scoring rubric is "a set of scoring guidelines that describes the characteristics of the different levels of performance used in scoring or judging a performance" [57]. Typically in the form of a set of ordered categories to which the work of interest can be compared, it specifies the qualities or processes that must be exhibited for a performance to be assigned a particular evaluative rating [58]. Rubrics are usually employed when a judgment of quality is required; they have been used to evaluate a broad range of subjects and activities [59]. An analytic scoring rubric allows for the separate evaluation of multiple factors with each criterion scored on a different descriptive scale [60]. Engineering educators have de-

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veloped rubrics for an increasing number of applications. For example, Moskal, Knecht and Pavelich have successfully used rubrics to assess students' performance on design projects [61].

Holt *et al.* [62] developed a rubric to assess ethics in a business school setting provided a starting point for our rubric as did Pinkus, et al. who assessed bioengineering graduate students' analyses of ethics cases [63]. This latter tool was developed as a course assessment instrument informed by their work with the PETE project where a pre and post test design was used to better understand how students reasoned in ethics cases using the Harris, et al method. Pinkus focused on five "higher order concepts" which we then incorporated into our rubric's higher levels.

A quasi-experimental design was used to obtain students' written responses to the dilemmas contained in the scenarios. The cohort consisted of 39 junior and senior Pitt engineering students enrolled in an ethics-related course (fall 2002). The pre-test (*Artificial Heart* and *Borrowed Tools*) was administered on the first day and the post-test (*BioVis* and *Trees*) at the end of the term. Responses were coded and transcribed to remove any bias introduced by the respondent's handwriting or identity. A nine person rubric development team with participants from engineering, philosophy, and bioethics reviewed the student responses to the pre-test scenarios using a modified Delphi approach; i.e., assess-discuss-reassess. As a result, five components or stages were identified with four levels of achievement initially established for each. These five components were:

1) **Recognition of Dilemma:** This ranged from not seeing a problem to clearly identifying and framing the key dilemmas. As rubric development proceeded, clarification was introduced to distinguish a problem from a dilemma; i.e., problems have coincident alternatives, dilemmas have opposing alternatives that must be reconciled
2) **Information:** At the lowest level, respondents ignored pertinent facts or used misinformation. At the high end respondents made and justified assumptions, sometimes bringing in information from their own experiences.
3) **Analysis:** The lowest level respondents provided no analysis. Ideally, thorough analysis would include citations of analogous cases with consideration of risk elements with respect to each alternative.
4) **Perspective:** The lowest level revealed a lack of perspective, i.e., a wandering focus. The ideal is a global view of the situation; considering the perspectives of the employer, the profession, and society as well as the individual who is the focus of the case.
5) **Resolution:** The base level cited rules as the resolution, even if used out of context. The ideal case considers potential risk and/or public safety, and proposes a creative middle ground ("win-win" situation).

After the initial development, smaller groups of three to five rubric development team members met for subsequent sessions, continuing to use the modified Delphi approach. At the fourth iteration the rubric was expanded to five levels to increase its sensitivity and provide a centering level that allowed for better discrimination without any changes to the established categories.

Validation of the Rubric: By anchoring the highest level (5) on course assessment instrument developed by Pinkus and refined by Pinkus, Ashley, Golden and Fortunato [64], a degree of face validity was achieved. The involvement of the principals with an extensive background in engi-

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neering ethics and rubric development further helped to assure face validity. Also, level 5 corresponds to the framework recently proposed (independently) by Miner and Petocz [65]. However, to ensure that trained raters could achieve consistent results when applying the rubric, two raters used it to rate all pre (80) and post test cases (78), evaluating each one relative to the five components. The resultant case rating was the average score for the five components. Cronbach's alpha was used to obtain a measure of the internal consistency among raters. It yielded values ranging from 0.74 for the *Artificial Heart* scenario to 0.90 for *BioVis* indicating very good consistency for all four cases. As a second test of rater consistency, a series of Mann-Whitley (non-parametric) tests were performed between the raters for each of the five components. Non-parametric analyses were used because the response choices were ordinal. In 80% (or 16/20) of the comparisons, there was no significant difference between raters, while three of the four significant comparisons occurred for the pre-test cases.

An analysis of variance was used to discriminate between case and rater effects. There was no significant difference between the two raters, but there were differences among the cases. A Tukey post-hoc analysis revealed that the pre-tests, *Borrowed Tools* and *Artificial Heart*, were grouped together; as were the post-tests, *Trees* and *BioVis*; e.g., their ratings were not significantly different. These results indicated that the rubric was generally applied consistently by the two raters and that there was a distinction between pre- and post-tests. The latter point suggests aggregate progress by students upon completion of the course; e.g., an increased understanding of the professional and ethical responsibilities of an engineer. It suggests that the rubric could be used to assess learning gains. Consequently, the two raters' scores were averaged to obtain a rating for each case and then ratings of the pre and post cases were averaged respectively to obtain pre and post assessments for each student. There was an average gain of 0.47 from pre-test to post-test. While eight students (21%) showed a decline in performance (ranging from -.05 to -0.9), one student's scores didn't change at all, and 30 (77%) showed improvements (ranging from 0.05 to 3.00). A third of the students had gains of 0.75 points or more (nearly a full level).

Having validated the rubric, we were then interested in seeing if there was a way that we could obtain comparable information by having students respond to statements rather than having to provide a written response. To do this we first presented students with three cases to read and then asked them to respond to a series of statements that covered the five moral problem solving stages. Five statements were created for each stage based on the five levels defined for the rubric. For each of the three cases (*Tools*, *Trees* and *Artificial Heart*) , 25 level statements were created (five stages and five levels for each). We asked a group of students to first provide a written analysis of the case and then indicate their level of agreement with each statement using a five-point Likert scale (strongly disagree, disagree, neutral or partial agreement, agree, strongly agree) . We also asked them to provide a relative ranking of the statements. An analysis of the resultant data was positive, suggesting that was this was an appropriate way to proceed.

Subsequently, we tested 120 students (from freshman to graduate) in this manner. We solicited undergraduate volunteers from those students currently enrolled in the School of Engineering at the University of Pittsburgh during the Fall 2003 term. These students had not necessarily had any instruction in ethics. We also invited graduate students from the Department of Bioengineering who registered for a Spring 2004 term course taught by Pinkus in Societal, Political and Ethical Issues in Biotechnology to participate in the experiment as part of a pre-test. All student

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volunteers were paid $25 to complete the assessment that took less than 90 minutes. As noted, the assessment consisted of three cases for which the students were asked to first provide a written analysis and then respond to a series of statements representing the five levels for each of the attributes (recognition, information, analysis, perspective and resolution) of the rubric. All case analyses were scored using the rubric by a single, trained grader for consistency. The following section provides the results of this study to date.

Results

Table 1 summarizes the results of this assessment. As shown in the table, there was no consistent pattern observed among the undergraduate students. However, in general undergraduates tended to score better on all three scenarios than did graduate students. This may be due to the more structured environment used for testing undergraduate students, which involved having a proctor in the room who explained the purpose of the study and was available for questions. Graduate students were given a written set of instructions and allowed to complete the assessment at their convenience.

Year	**Tools**	**Trees**	**Heart**	**Average Score**	**QPA**	**Sample Size**
Freshman	2.52	2.30	2.30	2.37	2.96	21
Sophomore	2.75	2.17	2.32	2.41	3.13	26
Junior	2.65	2.45	2.55	2.55	3.17	22
Senior	2.51	2.53	2.36	2.47	3.12	33
Undergraduate*	2.38	1.98	2.08	2.14	N/A	8
Undergrad Ave.	**2.59**	**2.34**	**2.36**	**2.43**	**3.11**	
Graduate	2.26	2.20	2.24	2.23	N/A	10
Overall Average	**2.56**	**2.33**	**2.35**	**2.41**	**3.11**	**120**

* Undergraduate student; year unknown (sophomore through senior)

Table 1: Summary of Student Evaluation

In general students performed somewhat better on the "Tools" case compared to "Trees" and "Artificial Heart." Table 2 summarizes the relative undergraduate and graduate performance for each of the five attributes.

Scenario	**Recogn.**	**Inform.**	**Analysis**	**Perspect.**	**Resol.**	**Overall**
Heart	**2.60**	**2.43**	**2.43**	**2.19**	**2.08**	**2.35**
Undergrad	2.61	2.45	2.45	2.19	2.08	2.36
Graduate	2.5	2.20	2.30	2.20	2.00	2.24
Tools	**2.96**	**2.72**	**2.60**	**2.34**	**2.19**	**2.56**
Undergrad	3.00	2.75	2.64	2.36	2.20	2.59
Graduate	2.40	2.20	2.10	2.101	2.26	21.6
Trees	**2.63**	**2.27**	**2.31**	**2.27**	**2.18**	**2.33**
Undergrad	2.65	2.26	2.32	2.28	2.20	2.34
Graduate	2.40	2.30	2.20	2.10	2.00	2.20
Overall Ave.	**2.73**	**2.47**	**2.45**	**2.27**	**2.15**	**2.41**

Table 2: Assessment of Each Component

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As shown in Table 2, both undergraduate and graduate students tended to do the best on *recognition of a problem*, and poorest on *perspective* and *resolution*. The average *recognition* score of 2.73 suggests that students tended towards the centering level; that is, they were able to recognize and frame an obvious dilemma, although they ignored other dilemmas imbedded in the case.

In contrast, students were assessed slightly above level 2 for *perspective*; i.e., only one perspective is taken rather than the centering level 3 in which multiple perspectives were acknowledged, although the subject tended to focus on only one particular perspective. Ideally, the student would consider multiple perspectives in analyzing a case. Similarly, the ideal situation for *resolution* is a "win-win" situation that finds a middle ground among the competing positions of all primary stakeholders. However, in general students were rated at slightly above level 2 because they either applied or cited a rule or simply listed possible alternatives without justifying a particular resolution. Undergraduates were between levels 2 and 3 for both *information* and *analysis*, while graduates tended to be closer to level 2 for both of these. For level 3 *information*, the student was expected to identify most of the key actors, justify relevant facts, and note that some information was missing. Level 2 is much less precise – facts are simply listed, some key facts may be missing or misinterpreted, and certain key factors are not identified.

For level 3 *analysis*, rules or standards are applied with some justification; possible consequences or conflicts are noted; the applicability of certain ethical concept(s) is recognized, and there is a recognition that the contexts of concepts must be specified. The *analysis* for level 2 is much less precise; the subject takes a less definitive position (e.g., "should do" vs. "must do"); minimal effort is given to analysis and justification; relevant rules may be ignored; the subject may miss or misinterpret key point or position, and if an ethical theory is cited, it is applied incorrectly.

Undergraduate students were asked to provide their cumulative grade point average and to list any ethics course that they may have taken. (The grade point average for freshmen was obtained after their first term was completed.) Only 17 of the 120 students had taken an ethics course. However, for the most part, neither having taken an ethics course nor having a relatively high GPA was strongly correlated with the rubric assessment. The former may be due to none of the subjects having an ethics course that focused primarily on engineering ethics as opposed to moral problem solving and ethical theories in general. Tables 3 and 4 summarize these results.

Factor	Scenario	Correlation
Grade Point Average	Tools	0.277
	Trees	0.266
	Heart	0.174
	Overall	**0.328**
Ethics Course	Tools	0.011
	Trees	0.134
	Heart	0.029
	Overall	**0.079**

Table 3: Correlation with Scenario Assessment Score

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Table 3 indicates that there was a modest amount of correlation between grade point average and the scenario scores, especially with "Tools" and "Trees." When the scores were combined and averaged, the correlation increased slightly to 0.328. There was practically no correlation between having taken an ethics course and the scenario assessment scores.

Factor	Scenario	Significance Level
Grade Point Average	Tools	0.018
	Trees	0.152
	Heart	0.270
	Overall	**0.019**
Ethics Course	Tools	0.991
	Trees	0.430
	Heart	0.991
	Overall	**0.514**

Table 4: Level of Significance – Kurskal-Wallace Test

Table 4 displays the results of Kurskal-Wallace non-parametric tests for relationship between grade point average and ethics course and the assessment for the various scenarios. Consistent with the correlation analysis, grade point average was significant for "Tools" and for the overall assessment score for the three scenarios. No significance was observed for having had an ethics course. Even though having had an ethics course was not significant, we did examine whether taking an ethics course made a difference when assessing particular attributes. These results are summarized in Table 5. Interestingly, it appears having completed an ethics course resulted in higher assessment scores for "Trees," for all attributes, but especially for *information*, *analysis*, and *resolution*, and the overall score which was 0.42 higher when compared to those who had not taken an ethics course. However, similar results were not observed for the other two scenarios. It is possible the difference occurred because of the nature of the "Trees" scenario which required students to balance the impact of possible harm to the environment against possible future loss of life. We found that a number of engineering students ignored the environmental issue and focused only on the safety issue.

Scenario	Recogn.	Inform.	Analysis	Perspect.	Resol.	Overall
Heart	**2.60**	**2.43**	**2.43**	**2.19**	**2.08**	**2.35**
Ethics course	2.76	2.41	2.65	2.24	2.18	2.45
No ethics course	2.57	2.44	2.40	2.18	2.06	2.33
Tools	**2.96**	**2.72**	**2.60**	**2.34**	**2.19**	**2.56**
Ethics course	2.94	2.82	2.53	2.41	2.12	2.56
No ethics course	2.96	2.70	2.61	2.33	2.20	2.56
Trees	**2.63**	**2.27**	**2.31**	**2.27**	**2.18**	**2.33**
Ethics course	2.76	2.71	2.88	2.59	2.53	2.69
No ethics course	2.61	2.19	2.21	2.21	2.13	2.27
Overall Ave.	**2.73**	**2.47**	**2.45**	**2.27**	**2.15**	**2.41**

Table 5: Relationship between having had an Ethics Course and Attribute Scores

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Conclusions

When the results of the two studies are taken together they suggest three conclusions. First, the earlier study [66] demonstrated that a course in engineering ethics could result in significant improvement in students' ability to recognize and resolve engineering ethical dilemmas. Second, as shown here, a wide spectrum of students who have not had such a course tend to perform at approximately the same level independent of their year (freshman through graduate student) or their academic performance as measured by their grade point average. Third, also as shown here, their level of performance may be somewhat below what we as engineering educators would hope that our students should be able to achieve. Fourth, having had a general ethics course, most likely offered through a department of philosophy, while certainly valuable from a general educational perspective, does not seem to help students in their ability to address specific engineering ethical dilemmas.

In particular, while students tend to be able to recognize the most obvious dilemmas and are able to begin to frame them appropriately, they are not yet able to also recognize other, more subtle but possibly more serious dilemmas contained in the short cases. That is, they tend to easily identify the more black and white dilemmas but are less able to see the gray ones. Their performance on the other attributes of our moral engineering problem solving "system" is even weaker – their ability to identify important facts, unknown (missing) facts and key actors should be better, as is true for their ability to analyze a case. Finally they are weakest in their understanding of the need to consider multiple perspectives (all key stakeholders) and finding a creative middle ground or win-win solution.

It should be noted that in the first study, "Tools" and "Heart" were used in the pre-test, while "Trees" and a fourth case, "BioVis" were used in the post-test. Since students in the second experiment scored highest on "Trees," and 0.21 and 0.23 on the other two respectively, this further underscores the almost half point gain that was observed in the pre-post experiment, suggesting that the gain was not due to characteristics of the case, even though "BioVis" was not included here.

Certainly we feel that our results to date indicate that a valid, reliable and "cost-effective" means for assessing students' abilities to identify and resolve practical ethics dilemmas can be developed. To the extent then, that well-designed ethics courses are introduced into the engineering curriculum or engineering ethical dilemmas and their resolution are integrated into several courses across the undergraduate and graduate curricula, these pedagogical approaches can be evaluated and refined. Whether or not these initiatives are supported by internal or external funds, those supporting these efforts will be able to determine whether or not students are learning the skills they need to become ethical practitioners.

Where are we going from here? We are currently experimenting with classification models (both neural net and statistical) to determine how best to relate the rubric scores to the students' responses to the next part of our test. That is, how do their reactions to the various statements that we asked them to consider (reflecting the different levels for each attribute) correspond to the assessment of that attribute obtained by using the rubric? Our objective is to develop a model or models that will take the pattern of student responses and predict the level of student attainment for each of the rubric's five components that we are examining as well as an overall level.

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This approach is similar to that of Cogito, in which 88 subjects used both the Cogito system and the interview process. Neural net models were then fit to this data and, as noted, correlations were obtained that were judged to be sufficient for aggregate program assessment measurements of groups of students over a long time periods. We plan to report on these results next year at ASEE.

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