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Development and Evaluation of a Model to Assess Engineering Ethical Reasoning and Decision Making*

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Little empirical research has been directed at team based ethical decision making, specific to engineering, and none (to the authors' knowledge) have studied the *process* of ethical decision making by engineers, an increasingly important issue given ABET's Criterion 3-f ". . . an understanding of professional and ethical responsibility". The objectives of this study are to: (1) investigate whether groups/teams of engineering students make "better" decisions than individuals when solving problems involving ethical issues, (2) evaluate and describe the processes used by the individuals and groups to solve problems that are ethical in nature, (3) and to assess those variables that potentially affect the quality of the resolution and the quality of the decision process. Two primary models: *Jones's Synthesis of Ethical Decision Making* descriptive model used in business and a normative *Harris, Pritchard, and Rabins (HPR) Model* widely used in engineering, combined with factors cited in the literature were used to form an *Ethical Decision Making in Engineering Model*. Using this model an experimental study involving both individuals and teams of engineering students solving ethical dilemmas was used to accomplish the research objectives. The results of this research suggest that teams achieve better results than individuals when resolving less complex ethical dilemmas. When complexity is increased both teams and individuals have difficulty obtaining satisfactory resolution; having completed an engineering ethics course also does not appear to improve the resolution. Processes that are used, as well as those significant factors identified, provide the engineering education community with an understanding about the degree to which a course in engineering ethics improves the ability and the quality of the resolution reached; and hence gives an improved understanding of professional and ethical responsibility.

Keywords: ethical decision making model; engineering students; engineering ethics

1. Introduction

Engineering decisions, including engineering design-related decisions, often involve ethical issues. These problems exist in the workplace and engineers typically have to deal with ethical dilemmas during their careers. Although basic character and personality traits are formed by the time students enter college, educators have the responsibility of contributing to the moral development of their students [1]. In Gilligan's words, "moral development in the college years thus centers on the shift from moral ideology to ethical responsibility" [1, pp. 8–9]. Engineering education is no exception.

Several studies in business ethics show overwhelming support for the importance of managing relationships within the group and the pervasive influence of peers in ethical decision making [2]. Yet, only a few studies have been conducted on teams solving ethical issues: and these studies were conducted from a business ethics perspective. Further, and more importantly, the studies focused on the outcome or final resolution, but did not evaluate the decision making *processes* by which individuals and teams solve ethical dilemmas.

The National Society of Professional Engineers (NSPE) and ABET (formerly the Accreditation Board for Engineering and Technology) have clearly supported the teaching of ethics in engineering. ABET's Criterion 3-f states that "engineering programs must demonstrate that their students have attained . . . an understanding of professional and ethical responsibility" [3]. Pfatteicher [4] suggests that demonstrating students "understand ethics" does not require that we assess whether or not students "behave ethically," either before or after graduation. Yet, we proposed that it is important for engineering educators to document and assess students' knowledge, approaches, or processes to solve ethical dilemmas, but not their actual behavior. Herein lies the basis for this study: *to evaluate those processes that engineering students use both individually and in groups when solving ethical dilemmas.*

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To date, much of the research associated with studying ethical decision making in organizations has focused on the business perspective and on individual decision making; little empirical research has been focused on team based ethical decision making that is specific to engineering. A better understanding of why and how both individuals and groups make ethical decisions in an engineering context should help improve ethical decisions made in professional contexts.

Here we study the process by which ethical decisions are made by engineering students—both individually and in groups. In general, when resolving ethical dilemmas, what strategies do groups use? Are these different for individuals compared with groups? Are the processes different for students who have completed an engineering ethics course compared with those without such coursework? What factors potentially lead a group to a low (or high) quality resolution? Do students place emphasis on professional knowledge, science and logic, professional codes of ethics when solving engineering ethical dilemmas or do they use their own personal biases and beliefs? Specifically, we attempt to address the following questions:

1. Is the quality of ethical decisions made by groups of student engineers better than those made by individuals? Are there differences between individuals and groups of engineering students with respect to the:
   - Quality of the resolution?
   - Quality of the decision making process?
2. Can a model for ethical decision making for teams be developed, evaluated and used to help assess engineering students resolving ethical dilemmas?
3. Particular to the process, what aspects (i.e., recognition, gathering information, analysis, perspective, etc.) do teams most often employ when making an ethical decision and how do they compare or contrast from those made by the individuals? In addition, what are the factors (i.e., level of educational experience, ethical training, etc.) that play a significant role in the quality of the resolution reached?

To achieve these research objectives, an *Ethical Decision Making in Engineering Model* was created and a study involving both individuals and teams of engineering students resolving ethical dilemmas was conducted to evaluate the model. Junior and senior engineering students were elicited from two courses in engineering ethics as well as from the general engineering student body. Both individuals and teams of students were videotaped solving two ethical dilemmas. Analysis of resulting videotapes was used to determine if differences between the comparison groups exist and to document the process(es) that are employed when solving ethical dilemmas/cases.

This paper is organized in the following manner. First a literature review of several ethical decision making models is included along with an overview of research on moral decision making and groups, as well as methods/instruments typically used to measure ethical reasoning is provided. This background literature has been used to develop the *Ethical Decision Making in Engineering Model* that is presented and explained in Section 3. The methodology Section 4 focuses on how this model is used along with a proposed experimental study to answer the research questions posed. Sections 5, 6, and 7 describe the results of the experiment respective to the three research questions. Finally, Section 8 discusses the outcomes, significance, and how it furthers the field of ethical decision making in engineering.

2. Literature review

Over the last thirty years, substantial research involving professional ethical issues has been conducted. Much has focused on business ethics and the individual decision making process.

Although various engineering societies have had codes of ethics for several decades, the academic discipline of engineering ethics first emerges in the mid-1970s when engineering and philosophy professors began to consider the ethical problems facing engineers [5]. Such disciplines as behavior and management sciences, law, history, and religious studies, combined with developments in other applied ethics fields addressing professional responsibility—medical, legal, and business ethics—also shaped the emerging field of engineering ethics [6].

Martin and Schinzinger [7] define *Engineering ethics* as the study of the moral values, issues and decisions involved in engineering practice. In that sense, clarifying such principles and applying them to concrete situations could be taken as the central goal of engineering ethics as an area of study. Pinkus et al. [8] presented a framework for engineering ethics that is based on the assumption that the engineer is a moral agent. To them an ethical engineer is one who is competent, responsible, and respectful of the public or, as they define it—Cicero‘s Creed II [9]. Competence involves both the acquisition of relevant knowledge, and the recognition of what is not known, or what expertise might be lacking by either an individual or a team. Responsibility involves communicating concerns about both what the engineer or team knows and do not know about the expertise needed to address the particular problem of interest. Cicero’s Creed—

to place the safety of the public above all else—is restated to require an ethical engineer to understand the risks associated with a given engineering design or recommendation.

2.1 Ethical decision models

A number of researchers have developed models involving ethical judgments, which can be grouped into: descriptive or positive models and prescriptive or normative models. Descriptive (positive) models are based on the cognitive processes that individuals use in making ethical decisions. They describe the ethical behavior that *actually occurs* individually or in the organization and identify those variables that influence the ethical decision making process. In contrast, prescriptive or normative models assume absolute truths about appropriate decision making and address the behavior that should follow. They may resemble a flow diagram or a set of rules for how to make an optimum or correct decision for a particular situation. As a result, they are typically limited to the application for which they were developed. This criticism of normative models has led to the development of descriptive models that seek to uncover important factors in a decision process involving ethical issues [2]. Such variables may include personal and organizational factors, as well as the characteristics of the dilemma.

We have found over fifty normative models in the literature, suggesting that there is a strong desire for a prescriptive approach to ethical decision making—i.e., one that determines an "optimal" or best decision, and how to arrive at an appropriate resolution. In contrast, a review of descriptive models illustrates a need to determine the factors that actually influence ethical decision making. For this work, we have synthesized two models: Jones' [10] *Synthesis of Ethical Decision Making Model* (a positive model that developed from business ethics) and the Harris, Pritchard, and Rabins model [5], widely used in engineering education (a normative model). A discussion of the evolution of Jones' model and a description of the Harris, Pritchard, and Rabins model are presented.

2.1.1 Positive models that led to the development of Jones' model

Jones developed his *Synthesis of Ethical Decision Making Model* from five earlier models. First, Ferrell and Gresham developed a *Contingency Model of Ethical Decision Making in a Marketing Organization*, which assumes that management has control over the organization's ethical decision making [11]. Next, Hunt and Vitell [12] developed a *General Theory of Marketing Ethics* model that focused on the way an individual perceives the situation, alternatives, and consequences. Concomitantly, Trevino presented her *Interactionist Model of Ethical Decision Making in Organizations,* based on Kohlberg's cognitive moral development model [13]. In 1996, Rest [14] published his *Ethics Model* based on the theoretical development of Kohlberg's theory of cognitive moral development and Ajzen and Fishbein's theory of reasoned action [15]. In 1989, Dubinsky and Loken presented the *Model for Analyzing Ethical Decision Making in Marketing* based on the theory of reasoned action [16]. Ferrell, Gresham et al. [17] developed the *Synthesis Integrated Model (SIM) of Ethical Decision Making in Business* based on the previous findings of Ferrell and Gresham, and Hunt and Vitell.

Integrating the various models developed by Ferrell and Gresham, Trevino, Hunt and Vitell, and Dubinsky and Loken, Jones [10] proposed the *Synthesis of Ethical Decision Making Model*. The foundation of this "fused" model is based on his *Issue Contingent Model* that uses Rest's four-stage process and introduces the concept that ethical decisions are contingent upon factors that define the characteristics of an ethical dilemma. Jones collectively refers to these as 'moral intensity,' which includes: Magnitude of Consequences, Probability of Effect, Social Consensus, Temporal Immediacy, Concentration of Effect, and Proximity [10]. In synthesizing the models, Jones provides an overarching model that incorporates the contributions of the individual models to the understanding of ethical decision making, which the previous models did not explicitly include.

As noted, Jones' *Synthesis of Ethical Decision Making Model* builds upon positive models presented and empirically studied in the business literature through 1991. We were not able to find other comprehensive, positive models in the more recent literature (last 20 years).

2.1.2 Normative models—Harris, Pritchard, and Rabins model

As noted, the literature contains well over fifty normative models, which are primarily application specific rather than comprehensive. One widely taught, general model for engineering ethics decision making was developed by Harris, Pritchard, and Rabins [5] and is shown in Fig. 1.

Searing [18] operationalized the HRP methodology and designated it as the *HARPS Ethical Analysis Methodology*. *HARPS* consists of four phases. The *information* phase involves investigating the problem and determining all relevant information including any unknown information (facts). The *issues* phase consists of asking questions about the information gained, clarifying terms and concepts, and finding missing information. The *analysis* phase

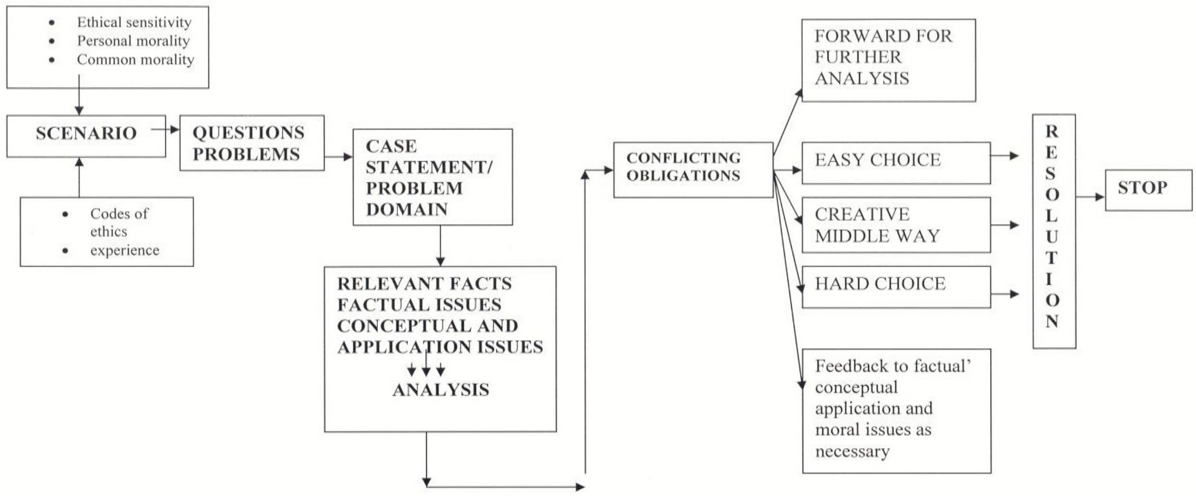

Fig. 1. Harris, Pritchard, and Rabins model.

suggests several methods (e.g., conflict resolution, line drawing analysis, utilitarian analysis, and respect for persons analysis), which, in turn lead to resolution. The *conclusion* phase consists of examining the results of all analyses performed and reaching resolution to the problem. We propose a combined Jones and HPR model, the *Ethical Decision Making in Engineering Model*, described in the next section.

2.2 Group decision making

An abundance of literature describes the value of teams, arguing that groups contribute to more effective organizational learning, decision making, and problem solving [19–21]. In organizational settings, the issue of group effectiveness acquired special relevance in recent years with a dramatic increase in the use of work teams, participative management, self-management, and total quality management (TQM) approaches [22–24]. However, with respect to ethical decision making, only two studies were found: Nichols and Day [25] measured the effect of group interaction on moral decision making using Defining Issues Test (DIT) scores to compare group with individual performance. Dukerich et al., investigated how groups reason about moral dilemmas [26], finding that subjects benefited individually from the group experience. These studies concentrated on how group work improved the individual's level of moral reasoning as measured by the DIT scores, where the test scenarios typically lack specific professional applications. Further, both studies were conducted on business school students. Most notably, neither addressed the *processes* used to arrive at the solution or whether or not groups solved ethical dilemmas better or differently than individuals.

2.3 Measurement of ethics

This section provides an overview of the various approaches that researchers have taken towards "measuring ethics." Several survey-like instruments have been developed as well as rubrics that can provide a performance appraisal. Among the variables influencing ethical decision making the most studied is the level of moral reasoning. The Character Education Partnership [27] provides an assessment index of the primary instruments used to measure moral reasoning. The instruments typically fall into two primary categories: those that "rate" moral development as defined by Kohlberg and those that take an "inventory" of an individual's moral values. These instruments are summarized in the following sections.

2.3.1 Instruments that measure the level of moral development as defined by Kohlberg

The *Moral Judgment Interview (MJI)* was developed in the 1980s with the purpose of operationalizing Kohlberg's theory on the stages of moral development. The MJI is designed to elicit a subject's (1) own construction of moral reasoning, (2) moral frame of reference or assumptions about right and wrong, and (3) the way these beliefs and assumptions are used to make and justify moral decisions [28].

The *Moral Judgment Test (MJT)* has been constructed to assess subjects' moral judgment competence as defined by Kohlberg: "the capacity to make decisions and judgments which are moral (based on internal principles) and to act in accordance with such judgments" [29]. It measures the degree to which a subject's judgments about pro and con arguments are determined by moral points of view rather than by non-moral considerations such as opinion-agreement. The MJT also measures subjects' moral ideals or attitudes, i.e., their attitudes toward each stage of moral reasoning as defined by Kohlberg.

Rest developed a non-interview measurement instrument called *Defining Issues Test* (DIT) and adapted the Kohlbergian perspective using the value of cooperation rather than the value of justice [14]. DIT is notably the most popular instrument and has been used extensively in over 1,000 studies. Numerous studies reported the test to have reliability in the 0.70 to 0.80 range [14, 30–31]. Finally, the *Social Reflection Questionnaire* measures stages of moral reasoning [32]. This questionnaire is simpler than the Moral Judgment Interview but more expansive than Rest's Defining Issues Test.

2.3.2 Instruments that evaluate or inventory moral values

A second category of "ethics measurement" has been labeled "inventories" of moral values. These instruments aim at describing individuals' ranking of moral values and/or categorizing them into various ethical ideologies. Specifically, the *Rokeach Values Survey* consists of a rank order exercise involving 18 terminal values (desired life goals; e.g., freedom, salvation, and equality) and 18 instrumental values (e.g., personal characteristics—cheerful, helpful, ambitious, etc.) [33]. The *Ethics Position Questionnaire (EPQ)* measures ethical ideology along two dimensions: relativism (the extent to which the individual rejects universal moral values when making moral judgments) and idealism (the extent to which the individual idealistically assumes that desirable consequences can, with the "right" action always be obtained). It classifies individuals into one of four ethical ideologies (situationism, absolutism, subjectivism, and exceptionism) [34–35]. The *Universal Values Survey* is used to present the theory of the universal aspects of human values [36]. The *World Values Survey* examines respondents' values in a broad range of areas: cultural, moral, economic and political [37]. The *Measure of Moral Values* consists of 15 statements that each pose a carefully constructed moral issue containing an identifiable element of injustice. Responses to statements are graded for "maturity of moral judgment." [38].

2.4 The Pittsburgh-Mines Engineering Ethics Assessment Rubric

The Pittsburgh-Mines Engineering Ethics Assessment Rubric (PMEAR Rubric) developed by Shuman et al., [39] evaluates the processes by which individuals make ethical decisions and parallels to the HPR model. Developed by researchers from engineering, philosophy, and bioethics from the University of Pittsburgh and Colorado School of Mines, its five attributes (described below) are each described by five levels of achievement.

1. *Recognition of Dilemma*. A continuum from not appreciating that a problem exists to clearly identifying and framing the key ethical dilemma(s).
2. *Information*. From ignoring pertinent facts to making and justifying assumptions.
3. *Analysis*. From providing no analysis to citing analogous cases with considerations for risk with respect to each alternative.
4. *Perspective*. From no perspective, or a single perspective to considering the global view of the situation, as well as such perspectives as employer, client, profession, and society.
5. *Resolution*. From simply citing rules as resolution to proposing a creative middle ground ("win–win" situation) resolution [39].

The PMEAR Rubric is used in this research to evaluate the quality of the resolution of the ethical dilemmas and to develop the categories of attributes for observation of students' resolving ethical dilemmas.

3. A conceptual model for ethical decision making in engineering

From our literature review, we have integrated two models—the positive Jones model and the normative Harris, Pritchard, and Rabins (HPR) model—and added five categories of factors influencing the decision making process to create a conceptual *Ethical Decision Making in Engineering Model*. The model is shown in Fig. 2, where the *team component* is highlighted with dash lines.

We propose that the factors influencing ethical decision making in engineering are:

1. *Problem characteristics*: level of problem's moral intensity;
2. *Individual attributes*: cognitive moral development level, moral level, ethical judgment, locus of control, ethical self-efficacy, self concept, attitudes about ethical dilemmas, personality characteristics, personal goals, ego strength, motivation mechanism, ethical independence, field dependence, ethical concern, motivation to comply, socialization practices, position/status, instrumental climate, subjective norm, normative beliefs, role conflict and role ambiguity, values, beliefs/religiousness, deontological/teleological evaluations, personal moral obligation, professional knowledge, engineering ethics knowledge, life experience, responsibility

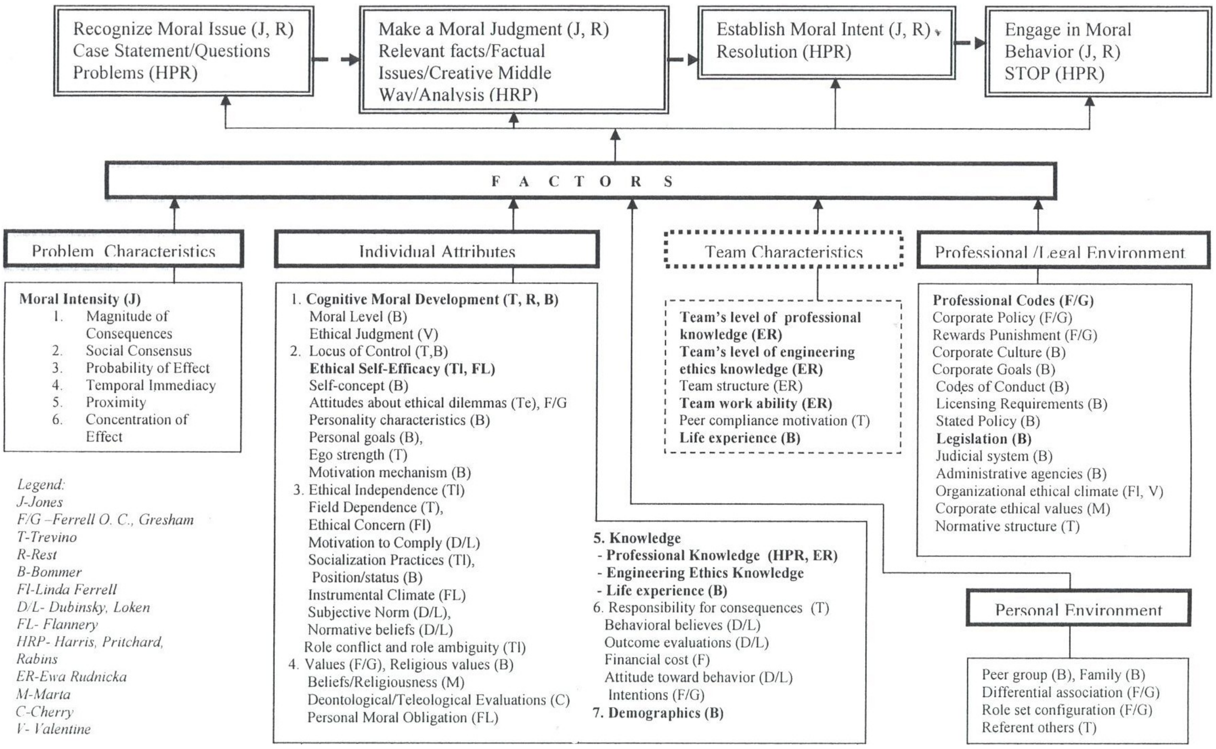

Fig. 2. Ethical Decision Making in Engineering Model (Legend: J = Jones [10]; F/G = Ferrell & Gresham [11]; T = Trevino [13]; R = Rest [14]; B = Bommer (Boomer et al. [40] 1987) ; Fl = Ferrell [41]; D/L = Dubinsky & Loken [16]; Fl = Flannery [42]; HRP = Harris, Pritchard, Rabins [5]; ER = Rudnicka [43]; M = Marta [44]; C = Cherry [45]; V = Valentine [46]; Te = Teague [47]).

for consequences, behavioral beliefs, outcome evaluations, financial cost, attitude toward behavior, intentions, and demographics;

3. *Personal environment*: peer group, family, differential association, role set configuration and referent others;
4. *Team characteristics* (where applicable): team's level of professional knowledge, team's level of engineering ethics knowledge, life experience, team structure, team work ability, peer compliance motivation; and,
5. *Professional/Legal environment*: professional codes, corporate policy, rewards/punishment, corporate culture, corporate goals, codes of conduct, licensing requirement, stated policy, legislation, judicial system, administrative agencies, organizational ethical climate, corporate ethical values, and normative structure.

The *Individual Attributes* in the conceptual model have been further categorized along seven subgroups: (1) level of moral development, (2) view of self, (3) view of self versus the peer environment/organization, (4) one's religious moral values, (5) one's knowledge, (6) one's ethical behavior/responsibility for consequences, and (7) one's demographics. The factors in bold in Fig. 2 are included in the experiment and are discussed in detail in the methodology section.

4. Methodology to evaluate the ethical decision making in engineering model

As noted, the purpose here is to determine how individuals differ from teams of engineering students in solving ethical dilemmas, especially relative to process and quality of resolution. To do this, an experiment was developed to evaluate the *Ethical Decision Making in Engineering Model*. The experiment involved both teams of engineering students and individuals solving engineering based ethical dilemmas. Approximately half of the participants (22 students) had completed an engineering ethics course; the other half (21 students) had no formal instruction in engineering ethical decision making. A description of the experimental design with the number of participants is presented in Section 4.2. Both the teams and individuals were videotaped while they completed their assigned tasks. This allowed us to observe behaviorally and assess the *processes* that teams and individuals used while solving the ethical dilemmas.

In doing the experiment, at least one variable from each factor was selected to be evaluated as shown in bold in Fig. 2. Figure 2 includes the factors influencing ethical decision making found in the literature by the authors. Please note that there are several models in the literature that included subsets of these factors. The Legend in Fig. 2 provides the authors who used the factors in their respective models. None of the literature based models included Team Characteristics or combined process variables with these potentially underlying factors. For the particular research study it should be noted that subjects came from an engineering student population at one particular university. As such this limited the selection of factors provided in Fig. 2 to those factors that are highlighted "in bold". For example, Moral Intensity was measured, as well as several variables noted under Team Characteristics, along with multiple Professional/ Legal Environment variables. Personal Environment was not measured because there was no particular instrument to measure this aspect and the subjects for the most part were homogeneous. Further, of the Individual Attributes, a portion of the variables were selected based on validity of instruments available.

Table 1 provides a description of each factor/ variable, the instrument, or methodology used to measure the variable, as well as how it was administered in the experiment. The factor "individual characteristics" consists of several sub-factors or sub-variables. Where applicable, a single instrument/method was selected to measure the particular sub-variable. Note that for "Problem Characteristics" the problem's moral intensity affects the depth

Table 1. Instruments used to evaluate the Conceptual Model.

Factor	Instrument/Measurement	Administration	Comments
Problem characteristics	*Moral intensity* A scaled instrument developed by Barnett, Brown and Bass [56] was used.	The scaled instrument took roughly ten minutes per scenario/ dilemma.	Two experts rated the scenarios/dilemmas to provide a standard for comparison purposes.
Individual characteristics	*1. Level of moral development* Cognitive Moral Development Level The Defining Issues Test (DIT) described previously was used to measure the level of cognitive moral development [57].	This closed form instrument took approximately 50 minutes for an individual to take.	Each individual or person on a team took the DIT prior to completing the ethical dilemmas.
	2. View of self View of self was measured using The Ethical Self-Efficacy Scale [50] was utilized to measure view of self. It rates an individual's perceptions regarding job skills, job qualifications, and the ability to perform on the job, and was chosen as a major indicator of how an individual views him/herself.	This information was acquired through a short five minutes survey.	Each individual or person on a team completed the survey prior to completing the ethical dilemmas.
	3. Knowledge Professional knowledge was measured in various ways: engineering knowledge (number of courses in field and QPA for these courses), engineering ethics knowledge (whether or not they have taken an engineering ethics course or related course and the grade for this course), and professional work experience (number of equivalent semesters of co-op or internship).	This information was acquired through student transcripts and a short five minutes demographic survey.	Each individual or person on a team completed the survey prior to completing the ethical dilemmas.
	4. Demographics Age, gender, engineering major was collected from each individual.	This information was acquired through a short five minutes demographic survey.	Each individual or person on a team completed the survey prior to completing the ethical dilemma.
Team characteristics	*1. Team work ability* The *Professional Developer*™ was used to obtain both a self-assessment of one's team work abilities as well as peer evaluations of each person [51].	This instrument took approximately 20 minutes to complete using a web version of the instrument.	Each individual participating on a team was asked to complete the assessment at the end of the study.
	2. Team's level of professional knowledge This information was obtained through Individual Characteristic (see 3. Knowledge).	N/A	N/A
	3. Team's level of engineering ethics This information through Individual Characteristics item 3.	N/A	N/A
Professional/ Legal environment	*1. Professional codes* Use of professional codes was obtained through behavioral observation	N/A	This was observed for both individuals and teams but not evaluated.
	2. Legislation Use of related legislation was obtained through behavioral observation	N/A	This was observed for both individuals and teams but not evaluated.

of the solution [2]. The "moral intensity" for the two cases in this study was evaluated using the instrument designed by Barnett et al. [48–49]. Two engineering ethics instructors rated the dilemmas' "moral intensity," and both concurred that Case 1 had a relatively low level while Case 2 had a significantly higher moral intensity level.

As shown in Table 1 there are four sub-factors (or sub-variables) for the "Individual characteristics" factor; and the *cognitive moral development level* is the primary individual attribute affecting the solution as evidenced by a number of studies. The DIT is the most widely accepted instrument to measure cognitive moral development; hence, it was selected for this study. The Ethical Self-Efficacy Scale [50] was used to measure *view of self*. It rates an individual's perceptions regarding job skills, job qualifications, and the ability to perform on the job, and was chosen as a major indicator of how an individual views him/herself. The attribute, *view of self vs. the peer environment and organization* was not used since the subjects were not in a professional organizational setting. Also, the *religiousness/moral values* variable was not evaluated since we did not believe it would produce sufficient variation, (i.e., most of the research has looked at a global religion perspective not a local religion perspective). For the *professional knowledge* both students' formal exposure to engineering ethics as well as professional experience (number of engineering courses completed, QPA, and number of equivalent semesters of engineering work experience) were used. QPA was used as a surrogate measure of professional knowledge since the subjects generally had limited work experience. Intuitively these attributes can affect the quality of the resolution and the quality of the process. The *responsibility for consequences* variable was not evaluated because the individuals/teams could only present a resolution, not implement it; thus actual ethical behavior could not be captured. Finally, typical *demographic* information was collected (e.g., age, gender, engineering major).

Here *Team Characteristics*, included the level of engineering knowledge, level of engineering ethics knowledge, life experience, and teamwork ability. The Professional Developer^{TM} [51] was used as an instrument to evaluate an individual's teamwork ability. For *Professional/Legal environment*, professional society codes and legislation were evaluated through behavioral observation; i.e., indications of the use of codes or legislation were specifically denoted. *Personal environment* was not evaluated in this experiment, since the subject pool was too homogenous in terms of peer group, family background, etc.

The behavioral observation method used to observe the subjects was employed using an approach developed by Besterfield-Sacre [52] and Besterfield-Sacre et al. [53]. The process of ethical problem solving can be best evaluated using 100% behavioral observation, since it enables researchers to investigate learning in real time [54–55]. Here, the attributes observed were taken from the PMEARS rubric [39]. Additional attributes (e.g., researcher cannot tell, non-productive activity, etc.) were included so that the observable set was mutually exclusive and exhaustive. To conduct the behavioral observation the time that each team member spent on a particular attribute was recorded, enabling the research team to know the amount of time spent on each attribute in sequence.

For each attribute visual and audio cues were developed through pilot studies. The complete list of ethical problem solving attributes, their definitions, visual queues, and audio queues is given in Appendix A.

4.1 Subject pool

The participant pool was drawn from enrolled junior and senior students at the University of Pittsburgh Swanson School of Engineering, including students who had or were within the last two weeks of completing an engineering course in either "Ethical Dilemmas: Balancing Cost, Risk and Schedule" (offered Schoolwide) or "Societal, Political, and Ethical Issues in Bioengineering". Both courses use the same required text and case study approach. Students volunteered to either work in groups or as individuals. For any team, all members had to be either "trained" or "not trained" in engineering ethics. The University's Internal Review Board (IRB) approved the Human Subjects protocol. Successful completion of the project by the students resulted in monetary payment of $65.00 for three to four hours of work.

Forty-three students participated in the study. Twenty-one students were male and twenty-two were female. Eighteen subjects were twenty-one years old, sixteen subjects were twenty-two years old, seven subjects were twenty-three years old, one was twenty-four years old, and one student was thirty-five years old. Except for one junior, all students were seniors; 16 were industrial engineers, 16 were bioengineers, and eleven were civil engineers. Out of the 22 students who took an engineering ethics course, 13 took the Schoolwide course and nine took the Bioengineering course. Twenty-one students had not taken an engineering ethics class. Of the engineering ethics students, two had taken additional non-engineering ethics courses. Three of the students in the group of "no engineering ethics" had taken a non-engineering ethics course. Thirty-three out of 43 students stated some degree of work experience ranging from 0.25 years to 4 years. Table

Table 2. Demographic information for the subject pool

Gender	Male—21, Female—22
Age	21 years old—18, 22 years old—16, 23 years old—7, 24 years old—1, 35 years old—1
Year of study	Senior—42, Junior—1
Major	Industrial engineering—16, bioegineering—16, civil engineering—11
Ethics course	School wide engineering ethics course—13, bioengineering ethics course—9, no engineering ethics course—21
Professional work experience	All students had some work experience 0.25–4 years

2 provides a summary of the above demographic information.

4.2 Experimental design

Table 3 provides a description of the experimental design with the number of participants. Both the teams and individuals were videotaped while they completed their assigned tasks.

All subjects participated in the study on a voluntary basis. The authors attempted to maximize and balance the number of participants for each treatment condition; however, given there was only one section of engineering ethics offered per year the subject pool was limited.

In addition to resolving two ethical dilemmas, participants were asked to complete a series of instruments that addressed the factors (in bold) in Fig. 2. To study the "processes" that engineering students used, the PMEAR Rubric was modified for behavioral observation. Data from the experiment were analyzed using descriptive statistics and hypothesis testing to determine significant factors. An empirical model was then developed relating the factors and process variables to the quality of the resolution.

4.3 Experimental logistics and facilities

The experiment took place in a secured room equipped with a sensor-tripped camera strategically placed to record student group activities. The "studio" was equipped with a table large enough to seat four people comfortably, a large white board, and a computer with MS Office and internet capabilities. The groups/individuals were scheduled to analyze Case 1 first then, on another day, Case 2, allowing up to 120 minutes per case scenario to discuss and create their responses. The time allowed was determined to be sufficient based on pilot study results. Upon entering the studio, student teams were given the case script and instructed to discuss it and then provide a written analysis noting all potential ethical problem(s) facing any of the actors (characters) in the case, the preferred resolution and supporting justification. The sessions were videotaped for the analysis. Similarly, individuals were presented with the same two case scenarios and given up to 120 minutes to "think out loud" about each case and provide their written responses. These verbal protocols were also videotaped while students worked on resolving the scenarios.

Although the verbal protocol and group discussions are different in terms of observation data, it is assumed that a verbal protocol should not affect the cognitive process involved in task performance as there is no indication that concurrent verbalization changes either the sequence or the content of the participant's thoughts. Verbal protocol analysis does require substantial time [58]; consequently many studies using this method are either case studies or small sample studies. Protocols have been successfully analyzed using methodologies by other researchers [58–59]. As with the groups, individuals also provided written responses.

Prior to the experiment, students were asked to complete the various instruments discussed above. The survey/instruments took approximately one hour per person. For those individuals working on teams, subjects had the additional requirement of individually completing the *Professional Developer* upon the completion of the cases' analysis [51]. This took no more than 20 minutes.

4.4 Case scenarios

Two engineering ethical scenarios were used in this experiment—"The Price is Right" (Case 1) [60] and "Carter Racing" (Case 2) [61]. Case 1 deals with not informing the client about changes in technical/specification of parts and costs. The

Table 3. Experimental design with number of participants/teams

	Exposure to formal engineering ethics instruction		**No exposure to formal engineering ethics instruction**	
	Individuals	**Teams**	**Individuals**	**Teams**
	7	5 (3 person teams)	9	4 (3 person teams)
Total	7	15	9	12

latter involves the potential loss of life. Students were sequentially presented with Case 1 followed by Case 2. As mentioned, the cases present different levels of moral intensity, issues of Cicero's Creed II [8], as well as engineering competency and responsibility.

4.5 Data collection, analysis and modeling, and validation

Two graduate student observers were trained to perform 100% behavioral observations' coding. In conducting these observations, only one team member was observed for coding at any one time. The observers were trained until they both achieved statistically similar results. The 100% observations were used to establish the amount of time associated with each of the eight attributes (i.e., aspects of the process). Tapes, as opposed to direct observations, were used in order to increase the accuracy, since the observers could review tape segments as necessary. To grade the resultant reports using the PMEAR Rubric, the two graduate students versed in engineering ethics were trained on randomly selected cases until they achieved consistency.

A statistical analysis was conducted on the various factors and processes that comprise the conceptual model. Two-sample F-tests for variances and two-sample t-tests for means were performed at the significance level of $\alpha = 0.10$ (due to the relatively small sample sizes). All five categories in the PMEAR Rubric were used to evaluate the Quality of the Report; hypothesis tests were conducted on the means for Individuals and Teams and for Ethics training versus No Ethics training to detect significant differences. Hypothesis testing was also conducted on the means for Individuals and Teams and for Ethics versus No Ethics training for all of behavioral observation categories to detect differences in "time spent" on each category. Finally, regression analysis was employed to detect which of the independent variables included in the conceptual model were significant.

5. Statistical analysis for quality of the resolution

To address research question 1, at the conclusion of the problem solving session the nine teams (five Ethics and four No Ethics Teams) and 16 individuals (seven Ethics and nine No Ethics Individuals) each prepared a written resolution for each of the two case studies. These were then evaluated using the PMEAR Rubric [39]. For each of the two cases and the five rubric categories, two-sample F-tests for variances and two-sample t-tests for means were performed for the following comparisons:

- Ethics (individual or all team members had completed an engineering ethics course) versus No Ethics (no individuals or team members had completed an engineering ethics course):
  1. Ethics Individuals vs. No Ethics Individuals,
  2. Ethics Teams vs. No Ethics Teams, and
  3. Ethics subjects vs. No Ethics subjects.
- Teams versus Individuals:
  1. Teams vs. Individuals,
  2. Ethics Teams vs. Ethics Individuals, and
  3. No Ethics Teams vs. No Ethics Individuals.

5.1 Case 1: Report quality for Ethics vs. No Ethics

For Case 1 (less intensive) we hypothesized that students with engineering ethics coursework would perform better (score higher) than those without ethics training on all categories of PMEAR Rubric (*Recognition of Dilemma, Information, Analysis, Perspective, and Resolution*) and *Overall Score*, regardless of whether they worked in teams or as individuals. In fact, we found that this was the case when comparing individuals, with statistically significant differences for all five categories and overall score; *P*-values were all less than 0.025, indicating strong significance.[1] In contrast, while we found that, when working in teams, students who had completed an engineering ethics course did *recognize* the ethical dilemma (Recognition of Dilemma, category 1) (t-test given equal variances, p-value=0.025) and analyze the scenario from multiple *perspectives* (*Perspective*, category 4) (t-test given equal variances, p-value = 0.055) better than students without such coursework, for *Information* (category 2), *Analysis* (category 3), and *Resolution* (category 5), as well as the overall score, no statistical differences between the Ethics and No Ethics Teams were found. In hindsight, *Information* and *Analysis* are functions that traverse the engineering problem solving process and students learn to perform these functions throughout the curricula. In contrast *recognition* of an ethical dilemma and viewing multiple *perspectives* are typically only "taught" in engineering ethics courses.

5.2 Case 1: Report quality for Teams vs. Individuals

For Case 1 we hypothesized that students working in teams would outperform (score higher) than individuals on all categories of PMEAR Rubric (*Recognition of Dilemma, Information, Analysis, Perspective, and Resolution*) and Overall Score. However, Teams performed better than Individuals only for *Resolution* (t-test given variances not equal, p-value = 0.072). This is possibly due to more

[1] Tables providing the statistical info can be found in the Ph.D. dissertation of Ewa Rudnicka [62].

Table 4. Case 1 report quality—mean in minutes (Std. Dev.)

Attribute	Ethics Teams $N = 5$	Ethics Individuals $N = 7$	No Ethics Teams $N = 4$	No Ethics Individuals $N = 9$
Recognition of dilemma	4.30 (0.200)	4.14 (0.143)	3.50 (0.333)	3.44 (0.465)
Information	3.70 (0.450)	3.93 (0.286)	3.25 (0.750)	3.00 (0.313)
Analysis	3.40 (0.675)	3.79 (0.238)	3.00 (0.166)	2.75 (0.214)
Perspective	3.90 (0.300)	3.71 (0.155)	3.25 (0.250)	3.22 (0.194)
Resolution	3.60 (0.425)	3.64 (0.226)	3.63 (0.063)	3.00 (0.250)
Overall score	3.80 (0.325)	3.71 (0.238)	3.38 (0.229)	2.94 (0.317)

discussion and points of view being presented by team members, which in turn, should lead to a better case resolution. This was confirmed in the video-tapes where the whole team typically tried to agree to the final resolution. Ethics Teams did not differ from Ethics Individuals for any category, which may not be surprising as all subjects had training in engineering ethics. When comparing No Ethics Teams with No Ethics Individuals, teams performed better only for *Resolution* (t-test given, unequal variances, p-value = 0.006), again confirming that using teams can lead to better performance if no ethics training is involved. The details of statistical tests for Case 1 are included in Table 4.

5.3 Case 2: Report quality for Ethics vs. No Ethics

Case 2 was longer and not as straightforward as Case 1. Compared with Case 1, it represents an engineering ethics situation that is more "vague" but with a higher "Moral Intensity" level. For Case 2, it was also hypothesized that students who had a course in engineering ethics would outperform students who did not have a course, regardless of whether they were on teams or not. However, this was not the case! Overall, there was no difference between students who had engineering ethics versus those who did not. For Teams, specifically, there were no statistical differences. When comparing Individuals, students with ethics training performed better only in the *Information* category than those who did not have engineering ethics training (t-test given, variances not equal, p-value = 0.009). However, when analyzing the students' responses the majority of subjects did not recognize the pertinent ethical dilemmas in this case. Many solved the case from a purely monetary value perspective and arrived at similar answers. Because many subjects failed to recognize the ethical dilemmas all scores for Case 2 were much lower than those for Case 1 along all attributes.

When looking at the differences between teams with engineering ethics and those without, only the mean score for the *Perspective* attribute was statistically higher for teams without ethics than those teams with engineering ethics (t-test given, equal variances, p-value = 0.097). For all other attributes no significant differences were found between the two sets of teams.

When comparing Ethics with No Ethics Individuals, a statistically significant difference was observed for only one attribute, *Information*. Here individuals with engineering ethics received a higher average score than Individuals who did not. Training in engineering ethics possibly enhances the ability to seek better information for cases with higher moral intensity.

5.4 Case 2: Report quality for Teams vs. Individuals

As with Case 1, it was hypothesized that teams, in general, would perform better on Case 2 than individuals. Further it was hypothesized that a course in engineering ethics would enable teams to perform better than individuals. Both teams and individuals exhibited overall lower scores for Case 2 compared with Case 1; i.e., they both did relatively worse on the more complex case.

In the case of Ethics Teams versus Ethics Individuals, Individuals performed better in *Information* (t-test, variances not equal, p-value = 0.028), *Perspective* (t-test given variances not equal, p-value = 0.046), and *Overall Score* (t-test given, equal variances, p-value = 0.080) categories, with no significant difference for the other three categories. For No Ethics Teams compared with No Ethics Individuals, no statistical differences were found. For Teams versus Individuals no significant differences were found for any of the attributes. In short, when comparing mean performance scores, many of the original hypotheses could not be confirmed. The mean scores for Ethics Individuals were found to be higher for Information and Perspective and their Overall Score attributes. Relatively low scores of 1.60 and 2.21 for the Recognition of Dilemma attribute in particular, but for all other attributes, indicate that majority of both Ethics Teams and Ethics Individuals failed to recognize the ethical dilemma in this more complex case. The details of statistical tests for Case 2 are included in Table 5.

5.5 Case 1 and Case 2 comparisons using report quality total scores

When comparing Case 1 and Case 2 reports it was found that Case 1 had higher mean scores than Case

Table 5. Case 2 Report quality—mean in minutes (Std. Dev.)

Attribute	Ethics Teams $N = 5$	Ethics Individuals $N = 7$	No Ethics Teams $N = 4$	No Ethics Individuals $N = 9$
Recognition of dilemma	1.60 (0.800)	2.21 (0.655)	2.25 (2.25)	2.11 (1.361)
Information	2.10 (0.425)	2.86 (0.060)	2.38 (1.229)	2.33 (0.250)
Analysis	2.20 (0.325)	2.43 (0.286)	2.13 (0.563)	2.11 (0.174)
Perspective	2.20 (0.200)	2.71 (0.238)	3.00 (1.333)	2.33 (0.688)
Resolution	1.80 (0.450)	2.36 (0.643)	2.63 (1.229)	2.00 (0.375)
Overall score	1.95 (0.388)	2.46 (0.300)	2.38 (1.063)	2.14 (0.470)

2 for Ethics subjects, No Ethics subjects, Teams, Individuals and for all subjects together, once again underlining the importance of the Case variable (moral intensity) (t-test given, all respective p-values less than 0.0005).

6. Statistical tests for behavioral observations

To address research question 2, both Teams and Individuals were videotaped so that the processes they used to resolve the engineering ethical dilemmas could be evaluated. The "time spent" for each attribute/category was recorded (in minutes). The first five categories correspond to the five categories in the PMEAR Rubric. Categories six through eight (Negative Impact/Not on Task, Waiting, and Do Not Know) were used when the subjects did not work on solving the case and therefore were not used in the analyses that follow.

As in the case of written reports, for each of the two cases and for each of the categories 1–5 two-sample F-tests for variances were conducted, and t-tests for means for "time spent" on categories 1 through 5 were performed to determine the following comparisons.

- Ethics versus No Ethics:
  1. Ethics subjects vs. No Ethics subjects,
  2. Ethics Teams vs. No Ethics Teams, and
  3. Ethics Individuals vs. No Ethics Individuals.
- Teams versus Individuals:
  1. Teams vs. Individuals,
  2. Ethics Teams vs. Ethics Individuals, and
  3. No Ethics Teams vs. No Ethics Individuals.

6.1 Case 1: Behavioral observations

For Case 1 we hypothesized that students who had training in engineering ethics would outperform (spent more time) than those without ethics training whether working in teams or as individuals. We found that students with ethics consistently spent more time on *Recognition of Dilemma* (t-test given, variances not equal, p-value = 0.0017) and *Information* (t-test given, variances not equal, p-value = 0.0005), whether working in teams or individually. Further, Ethics Teams spent more time than No Ethics Teams and Ethics subjects spent more time than No Ethics subjects when analyzing the problem from different *perspectives* (t-test given, variances not equal, p-value = 0.0000), aspects of the problem solving process taught in an engineering ethics class. For individuals, the time spent on *Recognition of Dilemma* (t-test given, equal variances, p-value = 0.0385), *Information* (t-test given, equal variances p-value = 0.00715) and *Perspective* (t-test given, variances not equal, p-value = 0.0070) categories is greater for Ethics subjects than No Ethics subjects. This is possibly because ethics students learned to look for both known and unknown information and should have been better prepared to recognize ethical issues and then analyze the scenario from multiple perspectives; hence they should have spent more time on these categories. For all other attributes data could not statistically support a difference between ethics and no ethics subjects.

Thus we observed that Teams devoted more time than Individuals to *Recognition of Dilemma (*t-test given, variances not equal, p-value = 0.0492)*, Analysis* (t-test given, variances not equal, p-value = 0.000)*,* and *Perspective* (t-test given, variances not equal, p-value = 0.0061) categories. This may be due to more discussion and points of view being presented by individual team members that, in turn, lead to better recognition, information gathering and noticing different perspectives. As observed in the videotapes, all team members contributed to the process. Similarly, Ethics Teams were better than Ethics Individuals for these same three categories—*Recognition of Dilemma* (t-test given, variances not equal, p-value=0.0346)*, Analysis* (t-test given, variances not equal, p-value=0.0019), and *Perspective* (t-test given, variances not equal, p-value=0.0048). However for *Resolution* (t-test given, variances not equal, p-value = 0.0020) the opposite was found: Ethics Individuals spent more time than Ethics Teams for these two categories. Further, when comparing No Ethics Teams with No Ethics Individuals, teams performed better in the *Analysis* (t-test given, equal variances, p-value = 0.0008) category, again confirming that teams can lead to better performance/longer discussion if no ethics training is involved. Interestingly, in all three comparisons

Table 6. Case 1 Behavioral observations—mean in minutes (Std. Dev.)

Category/Attribute	Ethics Teams' members N = 15	Ethics Individuals N = 7	Team members N = 27	No Ethics Teams' members N = 12	No Ethics Individuals N = 9	Individuals N = 16
1. Recognition of dilemma	1.40, (2.04)	0.68 (0.15)	0.93 (1.50)	0.28 (0.13)	0.36 (0.08)	0.50 (0.13)
2. Information	11.42 (8.47)	12.46 (20.99)	9.81 (9.14)	7.79 (2.86)	9.57 (8.10)	10.84 (14.91)
3. Analysis	17.26 (12.49)	9.97 (20.51)	18.06 (28.62)	19.05 (49.81)	7.22 (38.71)	8.42 (30.82)
4. Perspective	1.04 (0.94)	0.24 (0.09)	0.70 (0.68)	0.28 (0.06)	0.22 (0.12)	0.23 (0.10)
5. Resolution	7.91 (57.74)	24.05 (97.77)	8.84 (70.26)	10.01 (89.90)	25.34 (279.40)	24.78 (188.56)
Total time	39.07	47.4	38.34	37.41	42.71	44.77

Individuals spent more time than Teams on *Resolution* (t-test given, equal variances, p-value = 0.0152). However, this may be due to how the behavioral observations were coded; i.e., in a team setting *Resolution* (discussion and report typing time) is a single person category leading to a lower average time for the teams. It also may be due to including report writing in this category. That is, typically in the case of Teams, one member typed the report while the other two were classified as doing something else. Table 6 provides the means and variances for each category.

6.2 Case 2 Behavioral observations

Case 2 presents a dilemma with a higher Moral Intensity than Case 1 and yielded somewhat different results. For all three comparisons Ethics Teams/ Individuals spent more time than No Ethics Teams/ Individuals only on *Analysis* (for Ethics subjects vs. No Ethics Subjects t-test given, equal variances, p-value = 0.0114; for Ethics Teams vs. No Ethics Teams t-test given equal variances, p-value = 0.0648; for Ethics Individuals vs. No Ethics Individuals t –test given, equal variances, p-value = 0.0624). This suggests that Ethics subjects, both in teams and as individuals, were committed to doing more analysis. Note the six minutes difference for mean time spent on Analysis for Ethics versus No Ethics subjects in Table 7. While it might suggest that subjects with No Ethics determined that there was no serious ethical dilemma, and, consequently did not feel a need to look for more *Information* and do further *Analysis*; however, both cohorts tended to miss the key ethical dilemma in the case when doing their analysis.

Ethics subjects spent more time on *Information* (t-test given, variances not equal, p-value = 0.0604) and on *Analysis* ((t-test given, equal variances p-value = 0.0114) than No Ethics subjects. This was also true for Ethics Teams versus No Ethics Teams (t-test given, variances not equal, p-value = 0.0864). For all other categories the statistical analysis did not support the hypotheses that students who took an engineering ethics course (Ethics) spending more time on components of the case than those who did not (No Ethics). That is, for the higher level of moral intensity case, the majority of subjects, either working in Teams or as Individuals, did poorly with *recognizing* and *resolving* the ethical dilemma; rather most simply analyzed the case from a monetary value point of view. As noted, for Case 1 (less intensive) in general Ethics subjects performed better than No Ethics subjects for *Recognition of Dilemma* and *Perspective*.

In examining time spent on *Recognition of Dilemma* (t-test given, equal variances, p-value = 0.0070)and *Resolution* (t-test given, equal variances, p-value = 0.0000) we found differences between Team members and Individuals, but surprisingly team members spent less time on these categories. Again, this may have been because both categories were defined as a single person category, which in turn lowered the average time for Teams. As noted, for *Analysis* (t-test given, equal variances , p-value = 0.0042), Team members spent more time on this category compared with Individuals, suggesting that the team approach facilitated more of a discussion in terms of case Analysis.

These results are different from Case 1 findings where Teams spent more time on *Recognition of*

Table 7. Case 2 Behavioral observation mean in minutes (Std. Dev.)

Category/Attribute	Ethics Teams' members N = 15	Ethics Individuals N = 7	Team members N = 27	No Ethics Teams' members N = 2	No Ethics Individuals N = 9	Individuals N = 16
1. Recognition of dilemma	0.31 (0.06)	0.60 (0.29)	0.93 (1.50)	0.32 (0.13)	0.77 (0.61)	0.69 (0.45)
2. Information	19.19 (11.29)	20.39 (33.22)	9.81 (9.14)	16.71 (32.82)	17.85 (29.49)	18.96 (30.71)
3. Analysis	19.40 (93.10)	13.22 (51.62)	18.06 (28.62)	14.33 (39.94)	7.71 (39.75)	10.12 (49.81)
4. Perspective	0.20 (0.05)	0.12 (0.06)	0.70 (0.68)	0.24 (0.07)	0.20 (0.13)	0.17 (0.09)
5. Resolution	5.64 (52.68)	23.67 (76.80)	8.84 (70.26)	5.47 (37.60)	17.14 (216.44)	20.00 (157.34)
Total time	44.74	58.00	38.34	37.07	43.67	49.94

Table 8. Independent variables in the regression model

Variable name	Units	Range of values
Work experience	Years	0–3.25
Gender	Male or Female	1 or 0
Age	Years	21–35
Major	IE, CE, BioE	Dummy variables D1, D2
Total credits	Total number of college credits	124–167
Engineering credits	Number of engineering credits	85–120
Ethics class	Yes or No	1 or 0
Team/Individual	Team or Individual	1 or 0
Total Self-Efficacy score (SEF)	Points on scale 1–5	4–20
P-score from DIT	In percent based on DIT score	10–50
Time behavioral observation (BO) categories: BO-category 1–Recognition of Dilemma, BO-category 2–Information, BO-category 3–Analysis, BO-category 4–Perspective, BO-category 5–Resolution	Minutes per each category	0.000–65.600
Case number	Case 1 or Case 2	1 or 0

Dilemma and *Perspective*. This suggests that ethics instructions prepare students with an ability to detect the ethical dilemma of lower intensity cases better and, in turn, discuss the problem from various perspectives. With the higher moral intensity case the teams appear to have missed the subtlety of the dilemma and "followed the leader" focused primarily on an economic analysis as the solution to the problem.

7. Regression models

To address research question 3, here we present three general regression models. The purpose for the models is to determine those variables that best account for the variation in the resolution. The first model provides the most influential variables in predicting the resolution for Case 1. The second model provides similar information, but for Case 2. For the third model, Case, a surrogate measure for moral intensity, becomes an independent variable. Because there were many "potential" independent variables, the set of independent variables was established by evaluating the correlations between all possible variables measured in this experiment based on the conceptual model. From the correlation analysis, the set of independent variables to be included is described in Table 8.

For each model, seven stepwise regression models were conducted. The response variable was the score from each category of the PMEAR Rubric (Attributes 1–5), one for the Overall Score and a one for the Total Score (sum total of scores for the five categories).

7.1 Case 1: Regression models

Results of the regression analysis for Case 1 Overall score and Total score models are included in Table 9. For the Total Score Model, the *R-square* was 0.493. The model consists of four variables.

1. Whether or not a student had engineering ethics; 30.3 percent of the variation.
2. The dummy variable, Major, accounted for 8.3 percent of variation showing that bioengineering subjects (BioE) performed significantly better (positive coefficient) than industrial engineering (IE) and civil engineering (CE) subjects.
3. Time spent on Perspective accounted for 6.4 percent of the variation with a negative sign on the coefficient indicating "less" time spent on Perspective (BO-cat 4) contributed to a higher total score.
4. Being on a Team accounted for 4.3 percent of variation.

In the Overall Score Model the *R-square* was 0.487 and the same variables were found to be significant with similar explained variation.

7.2 Case 2 Regression models

Results of the regression analyses for Case 2 regression models are presented in Table 10. The *R-square* values for the models are interestingly much higher than for Case 1, ranging from 0.594 to 0.799. In the

Table 9. Regression model for Case 1

Independent variable	Constant (intercept) β_0	D2-major	Ethics class	Team / Individual	BO-category 4 perspective	Total
Overall score model	$\beta_0 = 2.872$	$R^2 = 0.148$ $\beta_1 = 0.530$	$R^2 = 0.239$ $\beta_1 = 0.373$	$R^2 = 0.060$ $\beta_1 = 0.556$	$R^2 = 0.040$ $\beta_1 = -0.185$	$R^2 = 0.487$ $R_{adj^2} = 0.432$
Total score model	$\beta_0 = 15.157$	$R^2 = 0.083$ $\beta_1 = 1.911$	$R^2 = 0.303$ $\beta_1 = 3.268$	$R^2 = 0.043$ $\beta_1 = 1.183$	$R^2 = 0.064$ $\beta_1 = -1.295$	$R^2 = 0.493$ $R_{adj^2} = 0.439$

Table 10. Regression model for Case 2

Independent variable	Constant (intercept) β_0	Work experience	Gender	D1-Major	D2-Major	Ethics class	BO-category 3- Analysis	Total
Overall score model	$\beta_0 = 2.393$	$R^2 = 0.209$ $\beta_1 = 0.232$	$R^2 = 0.134$ $\beta_1 = -0.737$	$R^2 = 0.086$ $\beta_1 = -0.767$	$R^2 = 0.204$ $\beta_1 = -3.276$	$R^2 = 0.135$ $\beta_1 = -0.609$	$R^2 = 0.098$ $\beta_1 = 0.041$	$R^2 = 0.692$ $R_{adj}^2 = 0.641$
Total score model	$\beta_0 = 11.048$	$R^2 = 0.086$ $\beta_1 = 1.058$	$R^2 = 0.079$ $\beta_1 = -3.241$	$R^2 = 0.204$ $\beta_1 = -3.276$		$R^2 = 0.138$ $\beta_1 = -3.170$	$R^2 = 0.121$ $\beta_1 = 0.218$	$R^2 = 0.628$ $R_{adj}^2 = 0.578$

Total Score model, the *R-square* value was 0.628 and consisted of five variables. The highest contribution, 20.4 percent, came from the D1 Major variable showing industrial engineering subjects contributing significantly "less" to the final resolution than bioengineering and civil engineering subjects. Having had an engineering ethics course (Ethics Class) accounted for 13.8 percent of the variation. Time spent on Analysis (BO-Cat 3) accounted 12.1 percent of the variation. Work experience accounted for 8.6 percent of the variation while Gender accounted for 7.9 percent of the variation. The *R-square* for the Overall Score Model, was 0.692 and consisted of the same number of significant variables as the Total Score model with similar explained variation. Here both D1 Major and D2 Major variables show that industrial engineering and bioengineering subjects contributed "less" and performed significantly different than civil engineering subjects.

7.3 Regression analysis for the combined model

Results for the combined regression models are presented in Table 11. In Total Score Model the *R -square* value was 0.661 and it consisted of five variables. The Case variable accounted for 51.8 percent of the variation. The D1-major followed and accounted for 6.0 percent of variation and showed that industrial engineering subjects contributed significantly "less" (negative coefficient) than civil engineering and bioengineering subjects. The Gender variable accounted for 3.3 percent, and the BO-Cat 3 (time spent on Analysis) accounted for 3.1 percent of the known variation while Work Experience accounted for roughly two percent. In the Overall Score Model similar results were obtained with the total *R-square* of 0.663. In addition, more time spent on Perspective (BO-category 4 variable) accounted for roughly two percent of the variation.

In summary, for a case with lower moral intensity decisions (Case 1) having an ethics class does prove to be influential in producing good resolutions to ethical dilemmas. For the case of higher moral intensity decisions (Case 2), Work Experience was the critical variable as only a few of the subjects (Teams/Individuals or Ethics/No Ethics) recognized the ethical dilemma. The fact that the level of moral intensity is a critical variable was confirmed by the results of the third set of models (i.e., Combined model).

8. Discussion of research findings

This work contributes to the body of literature in two ways. First, an ethical decision making model for engineering with consideration for teamwork was developed; and second, to address the research questions this model was evaluated across two cases involving decisions of different levels of moral intensity. Comparing groups of students (those with training in engineering ethics versus those without such training) provides a better understanding of how a first course in engineering ethics might improve students' ability to resolve ethical issues and, consequently, lead to an improved understanding of professional and ethical responsibility. The results aid pedagogy by suggesting areas of the decision making process to emphasize when teaching engineering ethics. An unexpected finding was that Case 2, the more complex case (case with higher moral intensity), was not correctly resolved by the participants who did not recognize the ethical issue and in turn scored lower across all the attributes. These findings suggest that perhaps more

Table 11. General regression model

Independent variable	Constant (intercept) β_0	Work experience	Gender	D1-Major	Case	BO-category 3-Analysis	BO-category 4-Perspective	Total
Model F Overall s core	$\beta_0 = 2.092$	$R^2 = 0.022$ $\beta_1 = 0.138$	$R^2 = 0.031$ $\beta_1 = -0.39$	$R^2 = 0.054$ $\beta_1 = -0.400$	$R^2 = 0.508$ $\beta_1 = 0.234$	$R^2 = 0.031$ $\beta_1 = 0.016$	$R^2 = 0.017$ $\beta_1 = 0.230$	$R^2 = 0.663$ $R_{adj}^2 = 0.63$
Model G Total score	$\beta_0 = 10.580$		$R^2 = 0.033$ $\beta_1 = -1.822$	$R^2 = 0.060$ $\beta_1 = -2.12$	$R^2 = 0.518$ $\beta_1 = 6.564$	$R^2 = 0.031$ $\beta_1 = 0.096$		$R^2 = 0.661$ $R_{adj}^2 = 0.64$

emphasis should be placed during class case discussions on making students more sensitive to detecting the variety of ethical dilemmas across levels of moral intensity.

From our analysis of the Combined Regression Model it was shown that moral intensity as measured by the surrogate Case variable plays a significant role as to how students are able to resolve engineering ethical dilemmas, as it accounts for the majority of the variation in the model. For situations involving lower moral intensity decisions (Case 1) we found that knowing engineering ethics is critical for engineering students as the students with engineering ethics training consistently performed better than students without ethics training in all categories, whether working in teams or individually. When working in teams, students who completed an engineering ethics course were able to recognize the ethical dilemma and analyze the problem from various perspectives better than students without ethics training. However, Ethics Teams did not satisfactorily differ from Ethics Individuals for any category, which may not be surprising as all subjects had training in engineering ethics. Whether trained or not in engineering ethics, in general, Teams performed better than Individuals for the most important category, *Resolution*.

In addition, as shown by the behavioral observation, students trained in ethics spent more time on their case than did students with no ethics training. Subjects with ethics training, whether working in Teams or as Individuals, spent more time on *Recognition* of ethical dilemma and *Information*. In addition for *Perspective*, Ethics subjects spent more time than No Ethics subjects; and Ethics Teams spent more time than No Ethics Teams. Teams in general spent more time than Individuals on *Analysis*. However the opposite was true for *Resolution,* most likely due to the way the that behavioral observations were coded. For two categories, *Recognition of Dilemma* and *Perspective*, Teams spent more time than Individuals and Ethics Teams spent more time than Ethics Individuals as perhaps more discussion and points of view had to be considered in a team setting.

However as the moral intensity increased (Case 2) we found that overall there were no differences in terms of report quality between students who had engineering ethics versus those who did not. For Teams, there were no statistical differences between Ethics Teams and No Ethics Teams; and in addition, for Perspective the hypothesis proved to be in the opposite direction than intended (No Ethics Teams were better than Ethics Teams). When comparing individuals, Ethics Individuals performed better than No Ethics Individuals in Information only and, contrary to what was hypothesized, Ethics Individuals performed better than Ethics Teams for *Information*, *Perspective* and Overall Score categories. For Case 2, the case of higher moral intensity, in general and not surprisingly, Ethics students spent more time on *Analysis* than No Ethics students whether working in Teams or as Individuals.

In short, we found for the lower level of moral Intensity (i.e., Case 1) that teams performed better than individuals and teams whose members had been through an engineering ethics course were better able to resolve the ethical dilemma than teams without benefit of that instruction. While only two cases, given the consistency of the teams, we suggest that this result might be generalizable, at least for low intensity cases. For higher intensity cases, our results suggest that an introductory course may help, but isn't sufficient.

A regression analysis using the data for the two cases provides further insight. The derived models suggest that having had an ethics course and working in teams, as well as the moral intensity of the ethical decision are significant predictors of the overall case resolution as measured by the report quality. This confirms the value of both working in teams and having an engineering ethics course. In addition exogenous factors such as work experience and gender also were significant and suggest being factors that influence the quality of resolution.

9. Conclusion

A comprehensive, conceptual model for engineering ethical decision making was proposed based on the literature. A number of the model's variables were included in an empirical study and subsequent regression models. In the empirical study Moral Intensity was used to describe the Problem Characteristic. These included Individual Attributes Cognitive Moral Development (P-score on DIT), Ethical Self-Efficacy, Knowledge and Demographics. Team Characteristics were included using the results of the Professional Developer for team workability and the number of total engineering credits served as a proxy for the level of Professional Knowledge (and whether or not the team was versed in engineering ethics). Included in the model, but not the empirical study were aspects of the Professional/Legal Environment (codes) that were not brought up in student discussions.

The research study presents the results based on a sample of engineering students at a major university and was limited to the subject pool available. Another limiting factor was the use of only two case studies. Clearly, what is needed in future research is to study a wider range of teams, addressing cases involving a higher moral intensity domain, since the Problem Characteristics highly impact the quality of the resolution. A second area of future research lies in studying the pedagogy itself. The results of the regression model suggest that the type of engineering *student* influences the quality of solution and/or the type of engineering ethics *course* that the students take. Participants in this research, who had taken an engineering ethics course, took either a required class (in case of bioengineering majors), or as an elective offered to all engineering majors (here, civil and industrial engineering majors). Further analysis by the "*type*" of ethics course (i.e., teaching pedagogy, epistemology, content coverage, instructional quality) could provide a better understanding of best practices in engineering ethics training.

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Appendix A: Observable attributes, definitions, visual queues, and audio queues for ethical problem solving

Category	Attribute	Basic definition	Visual queues	Audio queues
1	Recognition of dilemma	This category outlines when a subject recognizes one of the key ethical dilemmas. This task is a single subject attribute (only reflective on the original speaker of the statement and not upon the rest of the group).	None	A statement by a subject that initially points out one of the major ethical issues involved in the case being studied.
2	Information	This category outlines when a subject is reading or speaking of material that is already currently present in the case study document given. This does not include any analysis into the case study. This attribute also contains managerial tasks as well as rereading to the group previously written conclusions. This can be a single subject or multiple subjects' task.	When the subject is reading or is looking at the original document presented to them. Typing only the facts of the case presented in the original document (a note sheet or outline of just the relevant facts).	Speaking between group members only about the facts presented, without going into the analysis of why or why not they are ethical/unethical.
3	Analysis	This category outlines when a subject is analyzing the facts in terms of how they relate and their contribution to the ethical problem at hand. This is a multiple subject task, meaning that it is reflective on other subjects if they are listening or actively participating in the conversation (in terms of analysis discussion).	From the listener's perspective, if they appear focused on the person speaking (in term of analysis) or seem anyway involved in the conversation. No typing is involved in the category. All typing of analysis is considered part of the resolution, as the group's written analysis is actually part of their final conclusion (resolution).	Speaking between group members in terms of analysis of the case. These conversations deal with the understanding of how the facts may/may not play a functional role in the ethical problems presented in the case.
4	Perspective	This category outlines when a subject brings an outside perspective in to the conversation. This will pertain mainly to outside examples that may seem relevant in understanding the case (how the Challenger case could play a significant role in understanding *Case Study 2. This is a single subject category.*	None	A statement by a subject of a relevant outside case that reflects on the current case study.

Category	Attribute	Basic definition	Visual queues	Audio queues
5	Resolution	This category outlines when a subject is speaking in terms of their overall conclusion of their analysis. This attribute is only referenced to the subject speaking of the resolution and not of those listening (listening will be listed under Analysis). While generally a single subject attribute, it can also be a multiple subject category when one subject is stating the resolution while another subject dictates the resolution on the computer or paper. Both subjects in this case would be considered in this category. All typing of non-informational nature is also included in this category.	Subject is typing in terms of analysis or resolutions.	Subject is speaking of the final conclusion of their analysis.
6	Negative impact/Not on task	This attribute outlines any actions that have a negative impact on the project. Negative impact can be defined as any action by a subject(s) that are off task of the project. This category can be single or multiple subjects related.	In most cases this will include playing with objects on the table and eating (though subjects may be able to eat while actively listening, so this may be an area where the observer may make their best judgment on the case in point).	Any conversations that are not within the scope of the project are deemed to be not on task and would be included in this category.
7	Waiting	This category outlines when a subject is waiting (but not negatively impacting) on another member to perform some task. This is a single subject attribute.	Waiting for another subject to finish typing is one example of this.	None.
8	Do not know	This category was established for rare occurrences where the subject may not be in visual view, heard via audio, or the viewer is completely unsure of the subject's categorical status. This is rarely used in most case studies performed.	Subject outside of the viewing window/camera.	Audio is muffled or subject cannot be heard.

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