Where Should We Begin? Establishing a Baseline for First-year Student Awareness of Engineering Ethics

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Abstract

The first year engineering design course at a research institution in the southeastern United States contains a unit in engineering ethics, most recently using an assignment to compare two cases of corporate neglect resulting in major damages, where one company paid a fine and the other did not. The students' essays enabled us to study their ability to exercise reflective judgement through these research questions: "How extensively can first year students apply the reflective judgement skills identified by King and Kitchener to the process of ethical decision making?" and "What aspects of the ABET Code of Ethics of Engineers are most meaningful to first year students?"

Sooner or later, nearly all engineers can expect to encounter problems in their workplace related to conflicting conditions, interests, and beliefs, for which there is no one correct solution, but a variety of available solutions from which to choose. The Accreditation Board for Engineering and Technology (ABET) identifies it as a learning outcome for accreditation. [1] Revised ABET standards for accreditation continue to include engineers' ethical and professional responsibilities. [2]

However, first year engineering students may not yet have the necessary knowledge or experience to deal with the often ambiguous or partially known nature of problems involving ethical judgement in an objective manner. One way to build this experience is to introduce engineering ethics in the first year, with case study descriptions and prompts for ethical decisions supported by available evidence. Our evidence was obtained from related reference materials along with students' interpretations of a code of engineering ethics. The learning outcome is awareness of professional ethics, enhanced by reflective judgement, both of which are necessary for informed decision-making. [3] "Reflective judgement" is a series of cognitive stages from absolute certainty to probabilistic certainty based on the weight of available evidence and recognition of the legitimacy of alternative views. [3].

Student responses, in the form of phrases within sentences, were coded once using King and Kitchener's Reflective Judgement Model, along with keywords from the ABET Code of Ethics for Engineers. [4] Preliminary results revealed that many responses fell within the middle levels of the 7-level scale, with the most frequently mentioned keywords from the ABET Code being safety, health, public welfare, honesty and integrity. Many students regarded the ABET Code as a law, and stated that the company should be fined for violating it. Others considered the context of the two cases more closely, providing additional evidence of intentional neglect vs. human error, and recognized the views of two or more stakeholders in addition to their own perception of each case. These findings resulted in our baseline: first year students often do not consider views in contrast to their preferred view, and do not present sufficient evidence to support their own point of view.

Introduction

Engineering foundation courses cover a wide variety of topics, nearly all of which are expected to be useful to all of the engineering disciplines available at a given institution. One common topic is engineering ethics. Sooner or later, nearly all engineers can expect to encounter problems in their workplace related to conflicting conditions, interests, and beliefs, for which there is no one correct solution, but a variety of available solutions from which to choose. The Accreditation Board for Engineering and Technology (ABET) identifies ethics as a learning outcome for accreditation, specifically, "an understanding of professional and ethical responsibility. [1] Recently revised ABET standards for accreditation also continue to include the importance of engineers' ethical and professional responsibilities. [2]

One way to build an awareness of ethical responsibility is to include a unit in engineering ethics in first year engineering courses, with case study descriptions and prompts for ethical decisions supported by available evidence. Evidence is obtained from related reference materials along with students' interpretations of a code of engineering ethics. Since the resolution of ethical questions is often difficult, the use of reflective judgement in the evaluation of evidence can lead to better-informed decision making. [3]. "Reflective judgement" is a series of cognitive stages from absolute certainty to probabilistic certainty based on the weight of available evidence and recognition of the legitimacy of alternative views. [3]

The first year engineering design course at a research institution in the southeastern United States contained a unit in engineering ethics with an assignment to compare two cases of corporate neglect resulting in major damages, where one company was fined and the other was not. Students were asked to decide if both companies should have been fined, and to justify their decision with available evidence. The students' essays enabled us to study their ability to exercise reflective judgement through these research questions:

- How extensively can first year students apply the reflective judgement skills identified by King and Kitchener to the process of ethical decision making?
- How did students regard the ABET Code of Ethics of Engineers in their decisions and in conjunction with the exercise of reflective judgement skills?

In order to answer these questions, 144 essays were analyzed through directed content analysis, using codes derived from the King and Kitchener Reflective Judgement Model and the ABET Code of Ethics of Engineers. [3] [4] One round of coding was performed, and specific codes are listed in the Data Analysis section of this study.

Background and Theoretical Framework

The Reflective Judgment Model is a form of epistemic cognition identified by King and Kitchener that accepts and explores the role of uncertainty and context in the acquisition of knowledge, and its effects on the development of beliefs about specific types of knowledge. [3] These researchers identified seven stages in the development of reflective judgement, which appear in Table 1:

Table 1: King & Kitchener's Reflective Judgment Stages [3]

Stage	***Knowledge***	***Beliefs***
1	Is absolutely certain and concrete, based on observation	Need no justification, are absolutely true, other beliefs do not exist
2	Is absolutely certain but not immediately available, based on either observation or authority figure	Are unexamined or depend on the beliefs of an authority figure
3	Is absolutely certain (from authority figures) or temporarily uncertain (beliefs serve as substitute until absolute knowledge is available)	Are obtained from an authority figure or based on personal opinion without benefit of evidence
4	Is uncertain because knowing always involves some ambiguity; data are not always reliable and may be subject to error	Are based on evidence that is selected to support an idiosyncratic view
5	Is based on context, and is subjective because it depends on individual perception and criteria for judgement	Are influenced by context and context-specific interpretations; alternate beliefs are recognized as potentially valid
6	Is constructed as a series of individual conclusions about ill-structured problems; information comes from a variety of sources. Conclusions are based on evaluations of evidence across contexts and can be derived from the opinions of well reputed others.	Are justified by comparing opinions across different contexts; are formed by weighing evidence and the pragmatic need for action, such as being "sure enough" to act.
7	Is constructed as a series of individual conclusions about ill-structured problems; is re-evaluated based on new evidence or perspectives, or the availability of new tools of inquiry	Are justified by judging the strength of a position in terms of evidence, risk of error, consistency across contexts and consequences of alternative positions

This model is also informed by William Perry's model of intellectual development, as described by Pavelich and Moore. [5] Perry originally identified nine levels of cognitive skills leading to knowledge from a state of "right" vs. "wrong" to a state of awareness that knowledge is relativistic and context-bound, i.e., there can be many "rights "and many "wrongs." [5] This view supports the King and Kitchener model that knowledge is uncertain, depends on context, and, at higher reflective judgement stages, incorporates the changeable nature of existing and emerging evidence, along with recognition of the legitimacy of alternative beliefs.

Because the formation of knowledge and beliefs is influenced by a person's capacity for logic, objectivity and reflection, we also adopted a constructivist worldview or lens for this study. [6] [7]. Constructivism is based on the theory that individuals construct their own meaning about what they experience, through observation, analysis and evaluation, while accounting for past and current assumptions and the context in which these assumptions were formed. [7] Even though learning may also involve social interaction, it remains up to individuals to construct their own meaning from received information.

The relationship between reflective judgement and constructivist-type knowledge formation influences a person's understanding of the world as information is processed and compared to prior experience. [6]. Therefore, reflective judgement and a constructivist epistemology are not

only compatible, but also complementary. Further evidence of an individual's influence on their learning is the fact that it is internally interactive; the student relates what they have learned to what they already know, which is an individual construction. [6] This conclusion is also illustrated by the reflective judgement stages shown in Table 1, because evidence can be obtained from prior experience as well as from newly encountered sources. Ethical decision-making can depend on conclusions derived from one's experience, coupled with the acceptance of alternative beliefs as the interests of anyone affected by the decision, i.e., stakeholders.

Research Methods

This study involves the second of two one-semester introductory engineering courses, in which students pursue a design project in teams, coupled with individual development in certain technical and professional skills that are common to all engineering disciplines. A directed content analysis was employed, whereby a set of pre-determined codes is applied to a study to validate it and/or extend its applicability. [8] While this method would appear to be restrictive, it contains a provision that, if some of the data are not compatible with the identified codes, they may be analyzed in a later stage for the existence of either new codes or codes that are related to one or more pre-determined ones. [8] This method is also known as deductive content analysis, because our approach was operationalized in order to test the applicability of the King and Kitchener theory of reflective judgement. [9].

Study Context

Students completed a reflective essay as an assignment to compare two cases of severe neglect resulting in major damages, where one company was fined and assessed for damages and the other was not. Students were encouraged to use reference sources, including the ABET Code of Ethics of Engineers [4] to provide both additional background information and evidence for their decisions. The cases involved First Energy, whose actions caused a major power outage in the northeastern United States and Canada in 2003 (not fined or assessed for damages), and ExxonMobil, which was responsible for a major oil spill in Alaska in 1989 (fined and assessed for damages).

Participants

The participants were first year engineering students in two sections of the second semester introductory engineering design course, who had also participated in an in-class exercise in engineering ethics with a similar case study and ethical decision-making based on the views and interests of specified stakeholders. This introduced ethical decision-making. Groups of five students would explore the positions of assigned stakeholders and then report their interpretation of that stakeholder's position on the case study's ethical questions. We did not include prior instruction in the reflective judgement stages, because we wanted to find out what students would express without an intervention. Our goal was to discern a starting point for a lesson in reflective judgement, based on how well our students could already recognize and evaluate alternative points of view and use evidence to form their own positions.

Data Collection

Student essays were collected and de-identified in accordance with Institutional Review Board policy. The question that the students answered in their essays was as follows:

Consider the case of the Exxon Valdez, which polluted Prince William Sound with approximately 24 million gallons of oil in 1980. Exxon-Mobil was fined $150 million and settled associated damage claims. In comparison, should First Energy have been fined for the 2003 blackout, and/or required to pay damage claims, given the broad impact of the blackout? Justify your answers.

The companies experienced different outcomes for their actions because there was no legal requirement for First Energy to be fined, only a set of regulatory recommendations. Students were expected to exercise some form of ethical judgement in their decisions, by considering the context of each event, each company's responsibility to prevent it from occurring, and professional obligations indicated by the ABET Code of Ethics. One or more stages of the King and Kitchener Reflective Judgement Model were applicable because the stages are distinguished by variations in the reliance on authority as a source of knowledge and belief, as well as by variations in the strength of available evidence. These variations relate to possible decisions for the ill-defined or ambiguously described problems involving ethics, where reflection often reveals answers that are not immediately obvious.

Data Analysis

Student responses, in the form of phrases within sentences, were coded once using King and Kitchener's reflective judgement stages, as shown in Table 2 below. [3]. In addition, keywords from the ABET Code of Ethics for Engineers were applied as codes; these are also listed in Table 2. [4] The keywords were selected from an earlier engineering ethics study as having been remembered by students up to two weeks following the ethics unit, and are shown below in italics. [10]

Table 2: Codes for Directed Content Analysis of Student Essays Using King and Kitchener's Reflective Judgement Stages about Beliefs as Knowledge

Stage	Description
1	Absolute, formed through observation, no tolerance for other beliefs
2	Unexamined, justified by authority
3	Absolute, temporarily uncertain, justified through personal belief or authority
4	Use evidence to justify idiosyncratic beliefs
5	Contextual, subjective, interpreted by others, recognize alternative beliefs
6	Based on comparison of evidence from different sources and contexts
7	Based on the weight of evidence, risk of erroneous conclusions, strength of case presented

Table 3: Codes for Directed Content Analysis of Student Essays Using Keywords and Phrases from the ABET Code of Ethics of Engineers

Health, safety and welfare of the public
Honest/Honesty
Act in a professional manner/uphold the dignity of the profession
Serve with fidelity
Act impartially and objectively
Act only in fields of competence

Quality of this Study

Creswell has identified a large number of quality standards for qualitative research studies, such as the relationship between research questions and data collection/analysis, overall warrant, and value for informing and/or improving practice. [11] The verification of this study and its results is also an important issue for transferability and more widespread acceptance of our recommendations to the first year engineering community.

Verification procedures that apply to our study include prolonged engagement with participants' written responses, clarifying researcher bias (being clear about our own assumptions and biases), and peer review prior to any form of publication. Specific limitations include the possibility of researcher bias because of pre-determined code identification, as well as strict adherence to one and only one theory. [8] This could have been resolved through inter-rater reliability, whereby another researcher would also code the data, and both sets of results compared and reconciled where necessary.

Results

All of the 144 coded essays were categorized as Reflective Judgement Stages 3, 4, 5 or 6. Samples of coded text appear in Table 3 on the next page:

Table 3: Samples of Coded Text for King and Kitchener's Reflective Judgement Stages 3-6

King and Kitchener's Reflective Judgement Stages About Beliefs as Knowledge (3-6)		***Example Coded Text for Each Stage***
Absolute, temporarily uncertain, justified through personal belief or authority (3)		"This is a normal case of the government's laws being behind the technology and society we live in." "Such a large catastrophe should never go unpunished." "These [actions] are a blatant violation of the ABET Code of Ethics."
Use evidence to justify idiosyncratic beliefs (4)		"It would be only fair that First Energy would have to pay for damages…just as Exxon-Mobil had to pay for damages…" "The ABET Code of Ethics includes ensuring safety and security for the facilities, and these companies failed to do so." "following the ABET Code of Ethics prior to this experience could have prevented this catastrophe."
Contextual, subjective, interpreted by others, recognize alternative beliefs (5)		"Exxon was fined $150 million and settled for the associated damages….however, the court forgave $125 million in recognition that Exxon cooperated with the cleaning process….As set by the Exxon Valdez, I believe that First Energy should be fined; however, if they do comply and pay for damaged, the fine should be reduced." "In both situations, routine inspections and policies were ignored and they ended up causing devastating results." "There is a side that raises some questions as to whether First Energy was purposely violating the ABET Code of Ethics."
Based on comparison of evidence from different sources and contexts (6)		"A far greater number of companies and potential opportunities for human error were involved in the blackout than the oil spill, and the respective causes differed between the cases." "This event [First Energy blackout] probably sparked a lot of panic and fear throughout the region, especially because 9/11 had happened two years prior." "Although some of the mistakes were small and unintentional, they still caused a lot of damage and First Energy should be responsible for it. Even though there was no intent for damage to occur….they are still responsible for the problems [that] they caused."

The distribution of the essays among these four stages appears in Figure 1 below:

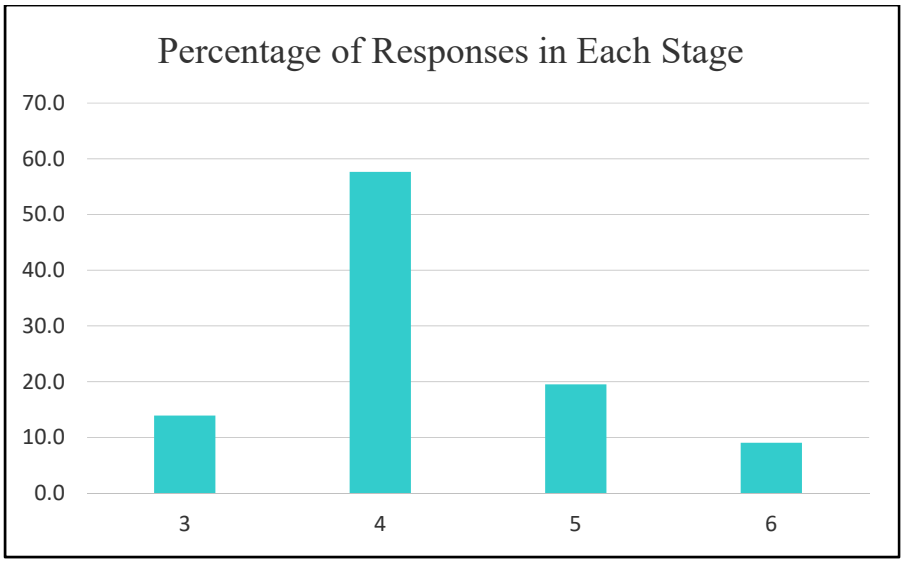

Figure 1: Participants' Responses Coded for King and Kitchener Reflective Judgement Levels

When the participants' responses were coded using the King and Kitchener Reflective Judgement Model, Level 4 contained the largest number of responses compared to the other levels. Many of these idiosyncractic responses contained quotations from the ABET Code of Ethics about health, safety and welfare of the public, to support a decision that First Energy should be fined because it "violated the ABET Code of Ethics" as if the Code was a law. These responses also contained a large number of assumptions that may or may not have been true. Participants in this category used evidence of negligence or human error from the case description to support their view that the company was culpable. They did not consider possible evidence in the company's defense or demonstrate a sufficiently thoughtful understanding of the impact of the blackout on First Energy's customers.

What distinguished Level 3 responses from the other levels was a regard of absolute certainty for the Code of Ethics as a law, with little mention of evidence to justify this view, as indicated in the sample text in Table 3. Many of these responses also used the phrase, "violated" or even "broke" the ABET Code of Ethics, and proceeded to cite the principle about holding paramount the health, safety and welfare of the public. Once again, the Code was considered a law, i.e., an absolute authority.

Level 5 responses contained the recognition of alternative views on the subject of fining the company, such as its potential effect on company finances and employees. There was also a more careful scrutiny of the available evidence about the actions of both companies, as well as consideration of the severity and timing of the applicable regulations.

Only 13 responses out of 144 were coded as Level 6, due to the number of reference sources described, and the number of different stakeholders, in addition to company employees, who were affected by the consequences of either event. The concept of stakeholder interests had been emphasized earlier in the course, so that students were familiar with it, but relatively few applied

this concept to the parties that were involved in, or affected by, the 2003 blackout. By considering not only damages caused by the blackout, but possible faults in company operations contributing to it, these responses allowed for human error and uncontrollable conditions, such as adverse weather, in their judgements. The role of applicable regulation, or the lack of it, was also a strong factor in the Level 6 responses.

Each essay contained statements that closely resembled only one reflective judgement stage, rather than multiple stages within the same essay. In addition, approximately 4-6 phrases within each essay indicated its overall reflective judgement stage. This was partly due to the length of the essay, and partly to the large number of students who viewed the ABET Code of Ethics as a law instead of guidance for the profession (i.e., the Level 3 responses), and therefore provided more limited evidence than the students whose essays were identified with Levels 4, 5, and 6.

In addition to health, safety and welfare of the public, additional keywords from the ABET Code of Ethics included honesty and integrity, such as First Energy's professional image and reputation, and charges of dishonesty by their failure to communicate problems to a utility partner. Several participants also implied that First Energy's mistakes were an indication of operating outside of their area of competence, but others dismissed this argument as human error or unavoidable conditions. A distribution of major keywords and key phrases from the ABET Code of Ethics appears in Table 4 below:

Table 4: Frequency of Key Words and Key Phrases from the ABET Code of Ethics

Keyword or Key Phrase	***Total Number of Responses in Levels 4-6***	***Percentage of Responses in Levels 4-6***
Health, safety and welfare of the public	78	59
Honest/Honesty	15	11
Act in a professional manner/uphold the dignity of the profession	12	9
Serve with fidelity	10	8
Act impartially and objectively	10	8
Act only in fields of competence	7	5

Discussion

Most of the participants understood the importance of context in judging whether First Energy should have been fined for the damages caused by the 2003 blackout, by comparing it to the damages caused by the Exxon Valdez oil spill, but their opinions varied as to whether the two events were comparable. Those who considered it comparable (mostly Levels 3 and 4 responses) were more likely to assign blame to First Energy for negligence and/or violation of the ABET Code of Ethics, and to suggest that the company should be fined. However, responses at Levels 5 and 6 indicated that the lack of mandates for best practices in electric utility operations meant that First Energy could not be fined, even if they actually deserved it, and were likely to

described extenuating circumstances such as severe weather conditions as contributors to the causes of the blackout.

The variety of idiosyncratic views expressed by the Level 4 responses is an example of how the participants constructed their own meaning from essentially the same sources of information about the oil spill and the blackout. [7] The apparent lack of recognition of alternate points of view in these responses further underscores them as idiosyncratic, especially with no reference sources. [3]

Conclusions and Recommendations

Additional coding, such as open coding followed by axial coding, may reveal other insights into the participants' processes of reflective judgement, particularly for those responses at Reflective Judgement Levels 4, 5 and 6, where the responses were more detailed and, in general, employed a wider variety of reference sources than those coded as Level 3. We have, however, identified a range of reflective judgement levels for first year students based on our results, along with aspects of the ABET Code of Ethics of Engineers that appear to be the most meaningful to first year students.

Knowing the Reflective Judgement Levels for our first year students further informs our efforts to prompt them to consider ethical dilemmas in engineering by carefully considering all available evidence before forming a judgement, and using an engineering code of ethics as guidance rather than as a law. It seemed to be all too easy to blame the case study's offending company for a willful disregard for the "health, safety and welfare of the public" per the ABET Code of Ethics, when it could have been judged on the basis of negligence, human error and mistaken judgement.

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