# Work in Progress: Assessment of Ethics Interventions in a First-Year Engineering Course

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## Introduction

Over the past several decades professional societies (i.e., ASEE) and accreditation boards (i.e., ABET) have increasingly required engineering programs to provide students with education about professional and engineering ethics. As a result, significant progress has been made at higher education institutions across the US in researching and implementing ethics educational interventions [1,2]. However, there remains a fundamental question of how to best assess the effectiveness of these educational interventions. While numerous quantitative and qualitative measures currently exist, they are often done exclusively post-intervention. Engineering programs typically do not assess students' ethical reasoning processes prior to engaging in the aforementioned interventions, nor do they typically track their development over the course of the semester.

The purpose of this work-in-progress is to develop a quantitative and qualitative framework for assessing the effectiveness of ethics interventions in a first-year engineering course at a four year engineering college in the Mid-Atlantic region of the US. This course was designed to introduce students to engineering design principles and the basic skills needed to be successful in their future careers as both engineering students and professionals - including the ability to recognize and resolve ethical dilemmas (that is, to perform *ethical reasoning*) in situations relevant to the engineering community. In particular, this study will examine how the ethical reasoning of first-year students changes over the course of their first-year curriculum when exposed to a specific set of ethics interventions, with the aim of answering the following three research questions:

RQ1: What is the baseline ethical reasoning profile of first-year engineering students before exposure to college-level ethics education?
RQ2: What are the effects of a specific set of ethics interventions on the students' ethical reasoning skills?
RQ3: What approaches do engineering students' use to resolve general and engineering-specific ethical dilemmas?

## Instructional interventions

The instructional interventions consist of a series of in-class and out-of class activities aimed at increasing the ability of students to recognize and resolve ethical dilemmas. The sources for these activities are a mixture of materials developed at the college and elsewhere. A brief summary of several of these activities follows.

### *In-Class Activities*

The in-class activities begin with an introductory PowerPoint presentation on engineering ethics that recaps the most salient features of different ethical theories and their relationship to real-world engineering case studies. This powerpoint also discusses the recognition of alternative viewpoints and weighing/balancing the responsibilities that engineers have to different groups (i.e., public safety, their firms, their coworkers, their superiors) The powerpoint then transitions into a Cards Against Engineering Ethics (CAEE) [3] game developed at the

University of Connecticut. The objective of this card game is to help students recognize alternatives in engineering ethical scenarios, in a playful environment. After the card game, a debrief session asks the students to reflect upon their choices during the game and reinforces the concepts of the lecture. Afterwards, a second brief powerpoint presentation takes a closer look at case study analysis, and focuses on the logical process of making ethical decisions. This powerpoint is supplemented by a short video on the Piper Alpha disaster, and leads to a discussion of engineering codes of ethics. The final activity is a group oral presentation, in which teams are tasked with researching engineering ethics case studies of their own choice. These case study presentations will be evaluated using the ABET Outcome 4 (formerly Outcome F) rubric for engineering ethics analysis [4].

*Out-of-Class Activities*

The in-class activities are supplemented with a suite of out-of class activities aimed at reinforcing the material learned in class. Out of class activities take place on two electronic platforms: the course ebook *Pathfinder* [5] and on the gamified homework platform Rezzly [6]. Pathfinder contains a chapter on engineering ethics which reviews different ethical theories, codes of engineering ethics, and sustainable engineering and is supplemented with a series of multiple choice questions which are assigned as homework. In Rezzly, students are able to pick and choose individual activities or "quests" that are related to engineering ethics concepts, among other activities. These activities are scaffolded and benchmarked to ensure that a minimum number of quests are completed in each subject area. The ethics quest topics include an introductory quest that introduces students to different ethical perspectives and two additional quest lines aimed at constructing/applying logical arguments and applying different ethical perspectives to the resolution of engineering scenarios.

**Methods**

First year engineering students from the host institution (N~96) will be invited to participate in this study to characterize and evaluate their ethical reasoning skills. The study consists of two related tests that assess the ethical reasoning of individuals when faced with ethical dilemmas. Additionally, a small group of students (N~5-10) will be invited to participate in a think-aloud study to provide further insight into how students reason through the ethical scenarios presented in the tests.

*Quantitative Instruments*

The tests consist of two related instruments – the Defining Issues Test version 2 (DIT-2) [7] and the Engineering Ethical Reasoning Instrument (EERI) [8]. The DIT-2 is designed to assess the ethical reasoning of individuals when faced with general ethical dilemmas, and is modeled on Kohlberg's theory of moral development [9]. In this test, a specific set of five (5) ethical dilemmas is presented to the individual, who must decide how to solve each dilemma. The individual is then presented with a series of statements, each associated with a specific Kohlbergian stage, which they must "Rate...in terms of importance"[7] from "Great" to "No Importance." Finally, they rank their top 5 statements in order of most to least important for each scenario. The output from the DIT-2 is a score profile based upon the prevalence of each Kohlberg stage in the students' rating and ranking data. An individual's score is broken down into four categories - Personal Interest (I), Maintains Norms (M), Postconventional (P), and N2.

The I, M, and P scores are calculated based upon the position and number of personal interest, maintains norms, and postconventional statements that were present in the student's top-five rankings. The N2 index is a composite of the P score plus additional information from the rating data, and was developed to determine the extent to which individuals eschew lower stage reasoning (I and M) and prefer higher stage reasoning (P). For further information on the DIT-2 and the N2 index, readers are encouraged to see [10]. The DIT-2 has been extensively validated and benchmarked for different age groups and levels of education [11]; for university undergraduates, the average scores and standard deviations for each category (n > 32000) are published in [11].

One limitation of the DIT-2 is in the lack of engineering scope within the scenarios presented. The scenarios are not always directly relevant to the engineering profession and lack a connection to the team-based skills that are often crucial elements of engineering decisions. The Engineering Ethical Reasoning Instrument (EERI) [8] is a tool designed specifically to assess ethical reasoning in *engineering scenarios* and has essentially the same format and scoring procedure as the DIT-2. To date, there are several ongoing engineering education studies that have incorporated the EERI including [12] and [13]. One study has found a significant difference in scores between the DIT-2 and EERI when administered to engineering students - in particular, engineering student scores on the EERI have outperformed the DIT-2 [13]. As such, it is hypothesized that the subject matter of the DIT-2 and EERI has an effect on the kinds of reasoning engineering students use to resolve the ethical dilemmas presented. However, these tests are not capable of capturing the details of this effect.

*Qualitative instrument - Think Aloud Protocol*

To better understand the kinds of reasoning employed by engineering students taking the DIT-2 and EERI, a small subset of the students will be asked to read a two (2) EERI and two (2) DIT-2 scenarios as a think aloud exercise. When faced with complex issues which have no definite answer - such as ethical decisions - the primary factor in a person's decision making is a type of reasoning called *informal reasoning* [14]. Informal reasoning is distinguished from formal reasoning, which is a solution method based entirely on application of formal logic to resolve problems. A study by Sadler and Zeidler [15] divides informal reasoning into three approaches - rationalistic, emotive, and intuitive. The rationalistic approach applies logic to the scenario, often by weighing alternatives or constructing cause and effect type arguments to support their decisions. The emotive approach relies on empathy towards the individuals in the given situation, and oftentimes individuals will rely on their personal experiences and feelings to help make a decision. Finally, the intuitive approach is an instinctual or initial ("gut") reaction to a given scenario, and is often the most difficult to identify.

During this think aloud, students will read through the scenarios and provide their decision to the ethical dilemma. They will then be asked to justify their decisions by answering a specific series of questions aimed at identifying the kinds of informal reasoning they used. As noted in [15], all three of these approaches may coexist in any individual's reasoning process, and thus the specific questions below are asked in the Think Aloud protocol to aid in identification of each approach to informal reasoning:

1. Explain the decision you arrived at for the provided scenario. How would you convince a friend of your position?

2. Can you think of an argument that could be made against your decision? How would someone support that argument?
3. If someone confronted you with that argument, how would you respond? How would you defend your position?
4. Did you immediately feel that your decision was right? Did you know your decision before you had to reflect on the scenario?
5. In arriving at your decision, did you take into consideration the feelings or perspectives of anyone else? If so, how did this affect your decision making?
6. Were there any trade-offs that you considered when making your decision?
7. Is there anything else that I should know about your decision making process for this scenario?

Responses to the think aloud will be audio recorded and transcribed by a third-party to enable coding analysis.

*Implementation*

The DIT-2, EERI and think aloud will be used in tandem to offer comparative and complementary insight on student ethical reasoning. For the quantitative instruments, half of the subjects will be given the DIT-2 and the remainder will be given the EERI. These instruments will be implemented using a pre-post testing model with the EERI/DIT-2 administered at the beginning of the semester and two weeks after the ethics interventions (five weeks after the pre-test). The think-aloud study will be conducted in the period between the pre- and post-tests.

*Analytical Methods - Quantitative*

To answer RQ1, The DIT-2 and EERI pre-test scores will be statistically analyzed to determine the average and standard deviations for the entire testing population. These average scores will be compared against the existing DIT-2 norms [11] and prior work [13] for consistency. The sensible difference between the DIT-2 and EERI pre-test scores will be estimated using Hedge's G and the standard p-test. To assess the effect of the interventions (RQ2), the same groups will be given the DIT-2 or the EERI as a post-test, and the difference in each student's score from pre- to post-test will be calculated using Student's paired T. The average difference and standard deviation will be calculated along with Hedge's G and p-tests. Population averages and standard deviations will also be calculated to determine if there is a sensible population-wide effect.

*Analytical Methods - Qualitative*

RQ3 will be answered by qualitative analysis of the transcribed responses to the think-aloud study. The think-aloud responses will be coded provisionally using Sadler and Zeidler's approaches to informal reasoning - rationalistic, emotive, and intuitive. In the first round of coding, multiple members of the research team will undertake the coding process of each transcript. Following this initial round of coding, the research team will meet together to discuss any discrepancies that may arise in the coding of different segments of the transcripts.

*Research Quality Considerations*

In preparing for this study, the researchers have referenced the Quality in Qualitative Research (Q3) Framework [16]. Prior work in moral development by Kohlberg [9] and informal reasoning by Sadler and Zeidler [15] have been reviewed to ensure high quality data and data analysis via theoretical and pragmatic validation. The testing procedure was constructed in a manner that avoids the influence of a power dynamic in the data collection (DIT-2 and EERI tests taken on private computers online) to provide procedural validation and the think aloud protocol questions are identical to those present in Sadler and Zeidler's work (procedural validation). The study is open only to first-year engineering students whose data will be anonymized and will be encouraged to respond freely and to share their thoughts and/or change their decisions at any time during the research process, allowing for communicative and pragmatic validation. Finally, review and discussion of the initial coding and maintenance of an audit trail of coding changes by the research team will allow communicative validation and process reliability.

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