Ethical Reasoning Development in Project-based Learning

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Introduction

This paper describes the method of ethics discussion used in Iron Range Engineering (IRE) and Twin Cities Engineering (TCE), two project-based learning engineering programs located in Minnesota. In alignment with the goals of both the Accreditation Board for Engineering and Technology (ABET) and the National Society of Professional Engineers (NSPE), the faculty in the program are working to improve the students' understanding of ethics in the engineering profession. Criterion 3-f of the ABET outcomes calls for student attainment of an understanding of ethical and professional responsibility; since both program's model of learning is to engage students in the practice of engineering, we seek to develop methods to improve understanding of ethics and ethical problems, which we believe should lead to increased recognition and process to best resolve ethical scenarios commonly encountered in engineering work. In line with the project-based learning program, the faculty believe that students will best learn to resolve ethical scenarios favorably by experiencing them, so we ask students to solve ethical problems commonly encountered by students and young adults, as well as ethical questions that arise in their projects. This paper describes this method of developing ethical understanding and decision-making processes in the context of project-based learning at IRE and TCE, sister upper-level general engineering programs in Minnesota.

Brief Background of Moral Development Theories

Kantian theory states that moral rules are universal and duty-bound, not dependent on the person, context, or environment involved in the ethical scenario[1]. Empirical research based on modern theories of ethics can help educators and students today. Kohlberg's theory of moral development assumes that justice and fairness are the basic building blocks of moral reasoning[2]. Kohlberg posited that moral reasoning develops with age, cognitive development, and exposure to moral conflicts. As a person experiences new moral scenarios that don't fit well within their current cognitive schema, cognitive disequilibrium results; the individual's successful integration of the new moral solution results in accommodation or movement to a higher level of moral development in a step-wise, upward manner. Kohlberg believed that moral reasoning would be stage consistent, and that an individual's moral behavior would be congruent with their cognitive level of moral reasoning[2].

Kohlberg identified three levels of moral development, each level having two stages:
    Level 1) the pre-conventional, at which neither moral rules nor social conventions are explicitly understood. In Stage 1 of Level 1, moral judgments are based on physical consequences of behavior; that is, avoidance of punishment and deference to authority constitute good behavior. Stage 2 moves to a pragmatic or hedonistic orientation in which moral judgments are based on what satisfies one's own needs.
    Level 2) the conventional, focuses on conforming to the norms of one's group. In Stage 3, moral judgments are based on pleasing others and living up to socially acceptable norms; Stage 4 includes maintenance of the common social order and following fixed rules.

Level 3) the post-conventional, provides a focus on the inner self and is more difficult to achieve. In these higher stages, the person is able to adopt a perspective outside of the particular social order in which the person was raised. Stage 5 is characterized by a "social-contract legalistic orientation"[1] in which moral rules are socially agreed-upon standards and are revisable only by general agreement of the society[2]. Kohlberg suggests Stage 6 as universal ethical principles, primarily justice, equal rights, and respect for individual dignity[1]. He writes that few, if any, ever reach this high level of moral reasoning.

Kohlberg found that most adults enter Level 2, the conventional level; they appear to understand concretely how society's rules apply to themselves and others, but many adults fail to develop the cognitive skills necessary to form abstract hypotheses or to consider several possible alternatives and their consequences[2]. Kohlberg's Level 3, post-conventional stage, requires abstract thinking and is rarely achieved, based on empirical studies so far[1,3].
An important question is which underlying factors contribute to a person's moral judgment and behavior as well as emotional regulation in that model[4,5,6,7,8,9]. Some of these factors are emotional regulation[10], social influences[11], and the desire to maintain cordial social relationships[7]; in summary, moral development, might be "bigger, messier, and more complicated than most investigators have wanted to think"[1].

Brief Background of Project Based Learning

Project based learning (PBL) is a different approach to teaching from traditional education. Students learn by seeking knowledge needed to answer a complex question. In our case, the question is an industry-sourced project that provides a solution for an external client. The students work on the projects in groups (between 3-6 students). They inquire and learn multiple core competency knowledge that they will need in order to complete the project. The knowledge needed to finish a project is multi-disciplinary and typically encompasses mechanical, electrical and biomedical engineering as well as project management. The students learn by doing and engage in rigorous discussions to find solutions. Faculty mentors assist them with the competency that they need but the knowledge sought is student-directed.

Group discussions are a central part of PBL. Project team members ideate and engage in discussions on the issues at hand and the knowledge needed to solve it. Discussions on ethical issues was done for the program in the same manner. A scenario in which ethical issues exist is introduced and students participate in group discussions on what would be the moral action to take. Different viewpoints are raised and debated. When no real ethical dilemma exists for the project on hand, theoretical scenarios that are possible are introduced to the discussions. The students hopefully learn how to resolve ethical issues appropriately through discussions on the impact that their actions would have on the project, their client, their team members and the public in general.

Finelli et al. shows that the most common method pedagogy for ethics instruction for engineering students comes from a lecture by a professor, and discussion of ethical issues with classmates is the fourth most common method of instruction[12]. The most common setting for ethics instruction is in an introduction to engineering course. In contrast, at IRE and TCE, ethics instruction is part of the discussion for each project that the students work on over four semesters of their junior

and senior years in college. The students are therefore introduced to ethical discussions throughout their college education. The pedagogy is through group discussions based on the project teams.

Ethics Instruction in the PBL Experience

Research evaluating the effectiveness of different methods for teaching ethics has compared the effectiveness of different pedagogies and suggested what may be more effective. Drake et al. compared the effectiveness of teaching ethics through specific modules as part of an existing course against teaching ethics in a standalone course[32]. There were no significant gains from either method compared to a control group and the paper suggests that ethics education be integrative and taught throughout the semester as well as to be discipline specific.

Kline suggests that teaching ethics though engineering disasters is not effective and suggests that ethics be treated as an everyday component of engineering education[33]. Bielby et al. evaluated different curricular approaches to ethics education[34]. The study has a large sample size that is distributed across 18 institutions across the nation. The study finds that the amount of exposure to ethics education does not produce improved student moral reasoning and may even be negatively correlated for lower class levels. The quality of ethics education that students are exposed to matters more and the deeper the cognitive depth of the exposure the better the improvement in scores. The paper also reported that the three most common methods of ethics education were presentations by a professor, a professional engineer or a guest speaker in an introductory engineering course. The problem is how the students relate to the presentations that they are exposed to.

Finelli et el. calculated the effectiveness of different ethic instruction approaches and settings[12]. Data was collected at 19 institutions, and it was found that the exposure to ethics education and knowledge of ethics education was high in both formal curricular courses and extra-curricular activities. The paper suggests integrating ethics instruction throughout the formal curriculum and connecting the students' extra-curricular activities to their formal ethics education.

Students at IRE and TCE receive integrated ethics instruction as part of their professionalism competency that they participate in every week. An ethical scenario is introduced by a faculty mentor to the student group for discussion and reflection. This scenario is either a situation which they may encounter in their college or young adult lives, or an ethical situation arising from the team's semester-long project. The faculty believe that this method results in deeper learning of the implications from decisions that affect real people and real projects.

The students debate the moral reasoning of different viewpoints and try to arrive at a conclusion that is agreed upon by all. However unanimity is not required, and students often draw different conclusions about the ethical ramifications of the scenario. The learning process adheres to the PBL pedagogy as the viewpoints and analyses are all done by the students. The conclusions reached are a result of their effort to analyze a complex scenario. Each student then reflects on his or her views in their reflection journals.

One example of an ethics discussion that arose from a team project involved balancing individual and societal values in business. The students' project was a method of sustainable agriculture called aquaponics, a symbiotic system of growing organic plants and fish for human consumption in a closed loop greenhouse with very little waste. This type of greenhouse provides wholesome fresh food to people, usually in the local area. The debate centered on disparate values of producer and customer. If a large retail store were to provide the capital-intensive greenhouse structure, the cost of the food would decrease, and production and availability of fresh, organic food would increase. This aligned with the students' stated values. However, the perceived values of the retailer differed. Using the retailer's distribution network would provide profits to a business whose human resources practices were perceived to differ from the team's values. If the team's goal to provide healthy, fresh food for as many people as possible were to be accomplished by indirectly supporting questionable human resources practices, an ethical problem exists. Without the business-provided greenhouse, the capacity for aquaponics food production would be diminished, and fewer people would benefit. This discussion was more meaningful to the students than a published ethical case since it directly impacted the work of the team on their project.

Another example of project-related ethics discussion arose from a team working on an entrepreneurial project. The goal of that project was to design a workable, marketable product during the semester. Ethics discussions arose during the design and product development stages. For example: Due to cost to manufacture, will the product only be available to wealthier families? What will be gained from this product and what will be taken away? Who should benefit from the product's use? How does the resulting waste affect people? Discussion of these ethical issues took place during the weekly design reviews. Each week, a group member would be assigned to look up all the ethical implications for a different stage in the process and share their findings with the rest of the group; this was followed by group discussion and individual written reflection.

Another team used a similar method for the ethics discussion while designing a medical device.

In the absence of ethical problems encountered on the team's project, the faculty provide a situation for the team to address. An example follows:

> You are working in a heavy industry that highly values safety and is strictly monitored. You notice that there is some oil spilled on a stair case that presents an immediate safety risk. However, the stairs can only be cleaned by a union worker but none are immediately available to help. Salaried workers have been cited and penalized for assisting with union work in the past, so you are apprehensive to do the job yourself. What should you do?

> If the penalty came in the form of a fine, would your decision change if the fine as $50, $500, $5,000? Are you liable if you do nothing?

The topics that faculty brought to the team were scenarios that the student may encounter in the early years of their engineering career or typical ethical issues commonly encountered by young adults and college students. Some examples follow:

- Parents disapproving of a new boy/girlfriend due to race, piercings, socioeconomic status, etc. – leads to a discussion on diversity awareness.
- Taking a quiz for an online class as a group, rather than individually, as the teacher expects. Is it really cheating if group quiz-taking results in better learning?
- Childhood vaccinations that may or may not lead to higher incidence of autism. Leads to discussion of motivation of pharmaceutical companies and the ethical obligations of parents who choose to vaccinate their child or not. Are research teams truly independent and unbiased?

Each of these weekly team discussions are followed up by individual written reflection.

There is a dearth of papers that shows the effectiveness of ethics education in PBL engineering programs as there are not many PBL engineering programs at all. Harasym et al. compares the effectiveness of a traditional lecture based ethics education against a PBL ethics education for medical students in Taiwan and concluded that a PBL model is more effective as the active learning done by the students engages both sides of their brains[35]. The PBL ethics approach for IRE and TCE is effective as they engage the students during their junior and senior year of college and the students are actively participants in the discussions. The discussions of ethical scenarios with other students provide experiences with greater cognitive depth which has shown to be more effective[34].

Contextual Factors and Moral Reasoning

It has been thought that the context of the ethical issue significantly influences the decision-making framework that people use. Women appear to be more likely to use a care-orientation when confronted with real-life ethical dilemmas[13], and men are more likely to use a justice-based approach when they confront workplace ethical scenarios[14]. Organizational/professional expectations may also be important in ethical reasoning; many organizational codes of conduct are justice-based and contain social and professional expectations for conformity. Societal and professional expectations do appear to significantly impact actual ethical decision-making; studies found that accountants, for instance, use only pre-conventional levels of reasoning when faced with realistic ethical dilemmas in the accounting field, even when they are cognitively able to use higher moral thinking[15]. Thorne found that accountants were more likely to respond to social factors rather than their higher-level professional judgment. Other studies also found that accountants' ethical decision-making processes were strongly influenced by interpersonal expectations as well as conformity to organizational and professional expectations[16].
The different socialization experiences of each gender group may be important in ethical judgments[17]. Carol Gilligan reasoned that women used emotions to a greater extent than men in deciding the most appropriate ethical actions in a particular case[10]. The empirical research provides inconclusive results. Several studies found that females were often more ethical than males, yet differences are not statistically significant[19,20,21,22,23].

Individuals tend to mature in their ethical attitudes and use more sophisticated moral reasoning as they assimilate new information into their existing cognitive/moral schemas[24,2]. Both education and age appear to influence moral development to some extent[25,19,26]. Borkowski et al.

meta-analysis of 35 studies involving over 16,000 students indicated that in many cases, older students respond more ethically than younger students, but the results were not conclusive[20]. Higher levels of education have also been shown to result in higher levels of ethical reasoning development[26, 27].

The particular major course of study does not appear to have a substantial impact on students' ethical development during the college years. Borkowski et al meta-analysis involving the ethical attitudes of undergraduate majors showed mixed results. In the 30 studies included, no relationship was found between college major and moral reasoning development. Mayhew et al. measured the ethical development of first year engineering students across 19 institutions across the country as part of a study to measure the impact of deep learning activities on moral growth[28]. The scores were measured before they started college and after they had completed a year of study. Their findings were that students who had taken more Science, Technology, Engineering and Mathematics (STEM) or health sciences courses posted lower end of year ethical growth. This might be caused by a lack of emphasis on ethical considerations in STEM and health sciences courses. The study concluded that students' ethical growth was highest when they participated in activities that expose them to multiple viewpoints and different perspectives of ethical issues.

Trice measured engineering students' pre- and post-ethics course ethical levels and found that ethics education, especially one that is geared for engineering students and engages their involvement, can significantly raise the reasoning levels[29]. The mean N2 score of the engineering students after exposure to ethics courses was 51. Loescher measured the N2 scores of business students who were exposed to ethical reasoning courses and found the means score to be 29.6[30]. This study also measured the N2 scores of engineering students in two particular programs.

The Survey Instrument

The survey used in this study, the Defining Issues Test v. 2, or DIT-2, provides a measure of moral judgment, based on Kohlberg's theory of moral development[2]. The online survey presents five hypothetical dilemmas. The respondents are asked to rank 12 issues for each of five scenarios, and these are analyzed by the Center for the Study of Ethical Development. The resulting N2 scores represent the degree to which the respondent used the Personal Interest (pre-conventional), Maintaining Norms (conventional), or Post-conventional Schemas, which correspond to Kohlberg's stages of moral development[2]. The DIT-2 is appropriate for people 9th grade and older of both genders and has a reading level requirement of age 12-13 years. The overall moral judgment development score, the N2 score, ranges from 0 to 100 and corresponds with Kohlberg's stages of moral development. Validity and reliability are strong in the DIT-2 survey.

Demographics and Descriptive Statistics for the Study

In the sample, all the participants were enrolled in the IRE or TCE programs and were juniors or senior majoring in General Engineering; several of the students are emphasizing mechanical or electrical engineering.

Early in the fall semester, 2013, 43 students were asked to complete the DIT2 survey instrument. Thirty-five surveys were returned by the scoring center as usable and complete survey data. Of these, nine N2 scores were well-below expected values (less than 10); these scores were much lower than expected values, so the researchers thought it was highly likely that these respondents did not take the survey thoughtfully. The participants were not compensated in any way for their time and effort in completing the survey, and completing the survey was not part of any course grade, so there was no negative ramification to a student if they were to rush through the survey. The researchers decided to exclude the nine N2 scores lower than ten. The researchers felt that these unexpectedly low values would skew the results to such a degree to make the results meaningless; the trade-off of a smaller sample size was felt to be justified. The final usable sample size was therefore 26. The demographic variables included gender, age, and education level.

Of the 26 usable cases, 3 (12%) were female and 23 (88%) were male. Participants were age 21 – 51 years old, mostly in the 20 - 23 year range (65%). Three students (11%) were over age 40. Demographic information regarding the sample's age range is shown in Table 1.

Table 1: Age range of participants.

Age	N	%
20	8	31%
21	5	19
22	3	11
23-28	4	15
30-33	3	11
42-51	3	11
	26	Rounded to 100%

Note: N = sample size

DIT-2 Results

The primary research variable in this study was cognitive moral development (CMD), reported as the participant's N2 score, which ranges from 0 to 100. The recommended cut-off values for N2 to indicate moral reasoning developmental stages are: pre-conventional/personal interest schema (0-27), conventional/maintaining norms schema (28-41), and post-conventional (>42)[31]. This sample had a normal distribution with a mean N2 score of 35.2, the Conventional Level, as shown in Figure 1. This value is in between the measurements from Trice and Loescher studies mentioned earlier.
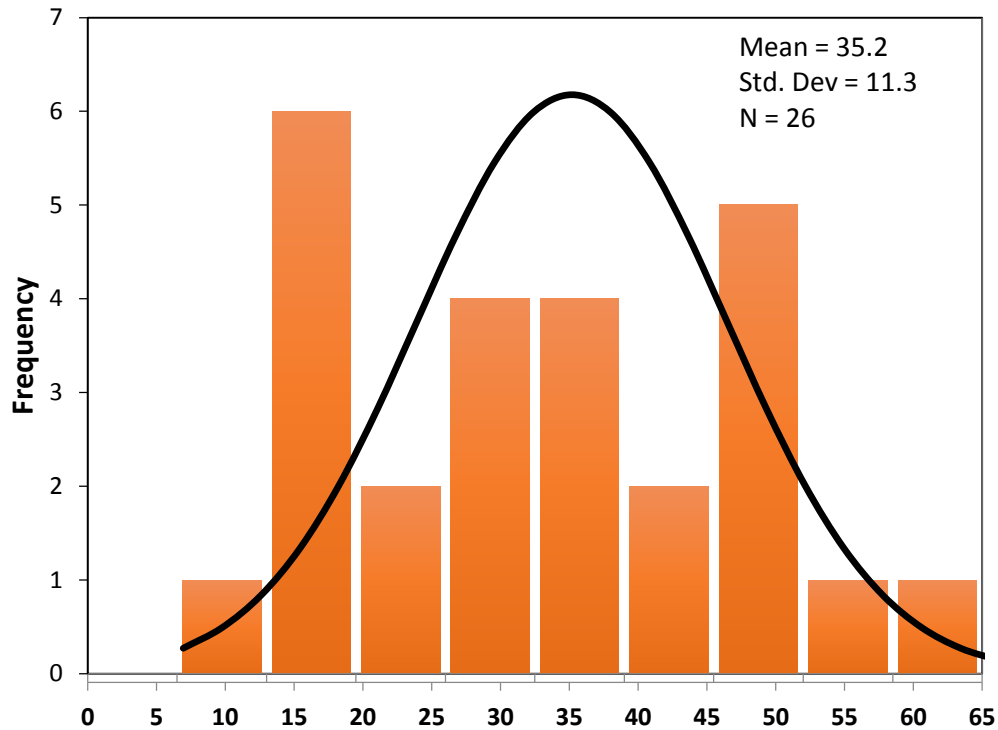
Figure 1: Histogram of Moral Development Scores.

Table 2 displays the mean, median, standard deviations, and variances for CMD (N2 Score) for the sample, segmented into the three stages of cognitive moral development.

Table 2: Sample Mean DIT N2-Scores by Moral Reasoning Stages/Schemas (N = 26).

CMD Stage	Cutoff Values	Sample Mean	SD	N	%
Pre-conventional/Personal Interest	0 – 27	21.9	3.4	8	31%
Conventional/Maintaining Norms	28 – 41	34.9	3.6	10	38
Post-conventional	42 or greater	48.7	3.0	8	31

Note: N = sample size; SD = standard deviation

Of the 26 participants, 31% scored within the pre-conventional reasoning stage, 38% scored within the conventional/maintaining norms stage, and 31% scored in the post-conventional stage. The highest N2 score was 56.1 and the lowest N2 score was 15.8. The overall mean score for the sample was 35.2 with a standard deviation 11.3. Table 3 displays the mean overall CMD scores by gender and age.

Table 3: Demographic with mean overall CMD Scores (N2)   (N = 26).

Variable	N2 Scores	SD	N	%
Gender				
Male	34.1	11.4	23	88%
Female	43.0	7.1	3	12
Age				
20 – 22	37.8	11.3	16	62%
23 – 28	25.0	11.0	4	15
30 – 33	40.5	7.6	3	12
42 – 51	29.0	5.0	3	11

Note: N = sample size; SD = standard deviation

The results show that women in the sample had a higher score (female N2 = 43.0) relative to the men (male N2 = 34.1) by 9 points. This difference suggests the women in the sample showed a greater capacity for moral reasoning when faced with forced-choice ethical dilemmas than did the men. This finding supports earlier research that found significant gender differences on this measure[31]; however, sample sizes were very small in this study.

In this sample, moral development by age groups was inconclusive. The 30 – 33 year age group had the highest score (N2 = 40.5) while the oldest age group (age 42 – 51) had a much lower score (N2 = 29.0). Surprisingly, the youngest participants had the second highest score (N2 = 37.8). Previous research indicates that moral development scores increase with age, but this study's result was inconclusive. This sample includes small sample sizes for each age grouping, so results are not statistically valid.

The DIT-2 is also significantly related to cognitive capacity measures of moral comprehension, and scores increase with moral education interventions. The DIT-2 score as been "significantly linked to many 'prosocial' behaviors and to desired professional decision making"[31]. The project-based learning model used by this college program allows ample opportunity for students to practice ethical decision-making in real-life ethical scenarios, guided by faculty. The paper also documents the ethical development activities and discussions that the students complete as part of the ethics curriculum during the year. The results inform engineering educators of the experience of using a particular ethical development curriculum model, specifically, small group discussions of ethical dilemmas moderated by team mentors and faculty members, followed by written student reflection.

Future Work

The faculty at IRE and TCE plan to continue to lead ethics discussions in small groups, then to measure any change in moral development levels during the academic year through a post-test administration of the DIT-2 survey. The results will inform the research team of any changes in

moral development in our student group, beyond the growth that is expected based on increasing age and experience. These results will be used to assess the effectiveness of the method of ethics instruction used. Pre- and post-test administration of the DIT-2 in following years is planned as a longitudinal study of growth in moral decision-making skills in this undergraduate engineering program.

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