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ORIGINAL PAPER

Using the Chernobyl Incident to Teach Engineering Ethics

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Abstract This paper discusses using the Chernobyl Incident as a case study in engineering ethics instruction. Groups of students are asked to take on the role of a faction involved in the Chernobyl disaster and to defend their decisions in a mock debate. The results of student surveys and the Engineering and Science Issues Test indicate that the approach is very popular with students and has a positive impact on moral reasoning. The approach incorporates technical, communication and teamwork skills and has many of the features suggested by recent literature.

Keywords Engineering ethics · Ethics education · Role-play · Constructive controversy · Debate · Chernobyl

Abbreviations

DIT-2	Defining issues test version 2
ESIT	Engineering and science issues test
ABET	Accrediting board for engineering and technology
RBMK	Reaktor Bolshoy Moshchnosti Kanalniy
NSPE	National society of professional engineers

Introduction

It is widely recognized that ethics plays a crucial role in the realm of engineering practice. Engineers are often required to make ethical judgments that can significantly impact not only their own careers but also the public at large.

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Educators and programs have long recognized the need to educate engineering students in moral reasoning and ethical sensitivity and an increasing body of literature related to teaching ethics in the engineering disciplines has developed, especially in the last 20 years or so. The Accrediting Board for Engineering and Technology (ABET) has for many years included accreditation criteria for engineering programs that address this need (ABET 2010). If for no other reason than seeking accreditation, modern engineering programs must grapple with the issue of providing effective ethics instruction for their students.

Not surprisingly, much of the literature has been devoted to best practices in the delivery of an ethics component in engineering education. Three basic approaches to teaching ethics in engineering can be identified: a semester-long course devoted to ethics, incorporating ethics into the existing curriculum, or a combination of these two approaches (Herkert 2002; Newberry 2004; Colby and Sullivan 2008; Borenstein et al. 2010). In terms of actual pedagogy, efforts seem generally to be divided into three categories: instruction in ethical theory, analysis of case studies, and service learning with an ethical dimension (Haws 2001; Colby and Sullivan 2008). There has long been a call to embed ethics—as well as communication, teamwork and design—throughout the engineering curriculum rather than concentrate on it sporadically (Harris et al. 1996) and the case study is most frequently used to achieve this integration (Colby and Sullivan 2008).

Case studies in ethics involve introducing some moral or ethical dilemma to students and then asking them to seek resolution. The case study can be historical or fictional and can involve dilemmas that range from everyday situations to disaster scenarios. There are a variety of approaches to treating the case study but the advantages of active learning techniques are well known (Prince 2004). Two popular active learning techniques include role-play and constructive controversy.

A role-play asks students to actively take on the role of stakeholders or participants involved in a situation. Role-plays may be seen as a subset of the more general technique of educational simulations. They have been studied extensively in many disciplines and are often used to introduce ethics (Rosnow 1990; Strohmetz and Skleder 1992; Brown 1994; Raisner 1997; DeNeve and Heppner 1997; Johnson and Corser 1998; Sanyal 2000; Bernstein and Meizlish 2003; Shaw 2004; Jensen and Richert 2005; Krain and Lantis 2006; Doron 2007; Jorenby 2007; Kraus 2008; Loui 2009; Poling and Hupp 2009; Brummel et al. 2010). Role-plays and simulations are known to have several benefits in the classroom including: promoting student motivation and participation, leading to deeper learning, "bridging the gap" between academic and practical knowledge in a discipline, and more effectively addressing learning styles than a traditional lecture (Hertel and Millis 2002).

Constructive (or structured) controversy was introduced 30 years ago (Johnson and Johnson 1979) as a way to engage students and deepen their understanding. It involves groups of students engaging in a debate-like discussion of some controversial issue, switching sides to argue the opposite point of view, and then collectively drawing a conclusion (Smith et al. 1981). This technique has also been studied extensively and is well-suited to exposing students to the nuances and open-ended nature of ethical decision-making (Ballantyne and Bain 1995; Johnson et al.

2000; D'Eon and Proctor 2001; Mitchell et al. 2002; Wareham et al. 2006; Bird and Erickson 2010; Tichy et al. 2010) While pure debate has advantages over individualistic study, both are inferior to constructive controversy (Johnson and Johnson 1985).

This paper describes a method using role-play and debate to integrate engineering ethics into a modern physics course. The role-playing and debate approaches were both chosen to motivate students and hopefully lead to a deeper understanding of ethical issues and the importance of competent ethical decision-making to the practice of engineering. While the debate format described does not follow the typical prescription for constructive controversy, it does include the salient features of the method. Students were solicited for feedback on the assignment and a tool to assess moral reasoning was applied as a pre-test and post-test.

Context

The Engineering Science program at <Author's Institution> is housed in the Department of Physics and Engineering. One of the program's distinctive features is that virtually every physics and engineering course which makes up the core curriculum includes a weekly 2-h lab period. These lab periods are devoted to a mixture of traditional experiments, computational problems, design projects, and any other projects or activities required by the syllabus. When the ABET criteria (ABET 2010) were incorporated into the program, a matrix was created that identified where in the curriculum each of the ABET Student Outcomes was addressed. It was decided to formally assess each of these outcomes in two or three of the courses spread out over the 4-year degree. A particular outcome may be addressed in many (or all) courses, but only a few instances were chosen for formal assessment and data collection.

Modern Physics is a sophomore level course that treats the typical topics of quantum, nuclear and solid state physics. It was recognized early on that this course lent itself to addressing the impact of engineering on society and to ethical issues, since many of the topics in Modern Physics are now finding their way into engineering applications (Hatfield and Zelinski 2010). Consequently one of the ABET outcomes that was designated for formal assessment in this course was "f. Students will demonstrate a knowledge of professional and ethical responsibility."

The author has had the responsibility for teaching Modern Physics since the inception of the Engineering Science program in 2007, including the treatment of engineering ethics. In a previous physical science course, the author noted that students are largely unaware of the Chernobyl incident and found the topic very interesting. It was decided that this would make a good case study in ethics and that it fits in well with the portion of the course devoted to nuclear physics and applications. The module on ethics ultimately became a somewhat lengthy project so this necessitated rearranging the typical sequence of topics so that nuclear physics was covered toward the middle of the semester rather than at the end.

Modern Physics is typically taken by students in the spring semester of their sophomore year. This means most students have only had exposure to engineering ethics during their first semester in the department's introductory course. In that course, students are introduced to the fundamentals of ethical theory and engineering codes of ethics, and they are guided through a few case studies. There is no formal engineering ethics course in the department but students are required to take an ethics course externally during their time at <Author's Institution>. At the time of this writing, no student entering Modern Physics had yet completed such a course so all students had a similar exposure to ethics.

Method

Incorporating non-traditional outcomes related to engineering into a Modern Physics course is a challenge. It was decided early on that these added pieces should not be perceived as content that was merely tacked onto the traditional topics students would expect in Modern Physics. As a matter of fact, the focus of the entire course was shifted from a basic science approach to that of an engineering course. An attempt has been made to integrate topics like engineering design, the impact of engineering on society, computational science, communication skills and engineering ethics in an organic way. The goal has been for the students to see these topics and required skills as growing out of the material in a very natural way.

Setting the Stage

Prior to the module on ethics, students have just completed a module on alternative energies where they are asked to do research on a cutting edge technology like fuel cells, fusion reactors, solar updraft towers or travelling wave reactors. They are then asked to perform a comprehensive assessment of the economic, environmental, and societal benefits and disadvantages, as well as the technological challenges involved in realization and implementation. This module fits in nicely with some of the early topics in the course since many of the newer technologies involve principles of modern physics that are finding their way into engineering applications. This also sets the stage to discuss nuclear power and the course is structured so that nuclear physics is being covered just as this module is ending.

Introducing the Topic

The introduction to the project is a fairly lengthy PowerPoint presentation that originally introduced the basic facts surrounding the Chernobyl disaster in 1986. In subsequent years, the PowerPoint has grown to include a discussion of nuclear weapons development, the Cold War, the development of nuclear power and the Three Mile Island incident. The purpose is to not only pique student interest—which it certainly does—but also to highlight the societal impacts that technologies can have and to illustrate the shifting nature of public sentiment and policy related to technology. Plentiful pictures and video capture the students' attention and have quite often led to extended question-and-answer periods and discussions. Students are fascinated by the Cold War era, the arms race and the development of such controversial technologies. Most are also unaware of the Three Mile Island and Chernobyl incidents, or have heard very little about them in their lives. The introduction ends with a basic account of the events at Chernobyl and a lengthier discussion of the literal and figurative fallout that followed.

Ethics Review

Before the assignment is presented to students, a brief review of ethical theory is conducted. This is felt to be necessary because it will have been at least a year since students were introduced to engineering ethics in the first-semester introductory course. The intervening sequence in classical physics is heavily populated by non-majors so it does not address engineering ethics to any significant degree. Thus far the introductory course has used one of two textbooks that include a variety of topics for beginning engineers, one of which is a brief treatment of engineering ethics (Holtzapple and Reece 2008; Oakes et al. 2009). Engineering codes of ethics are introduced along with some elementary ethical theory. After setting the stage for this project, students are reminded of the material covered previously and provided with documentation if necessary. The purpose is to refresh students' memories about the ethical theories that were introduced, the importance of engineering codes of ethics, and the way these were consulted during case studies. It must be said though that there is no real ethics instruction at this point. Students are given a quick reminder of what went before and provided with copies of pertinent sections of the text if needed.

The Assignment

The Chernobyl incident is well suited as a case study in ethics for at least two reasons. First, the incident is well documented. There is a wealth of information available not only about what occurred but also about what it means. This information ranges from official sources to first-hand accounts and has the added benefit of presenting students with different—sometimes contradictory—perspectives. Secondly, an analysis of the incident and the causes leading up to it make it clear that there is plenty of blame to go around. While it is certainly possible to restrict the focus to the decisions that were made that night in the control room, it is also possible to expand the focus to include the decisions made during the construction of the plant and the decision-making environment that existed at the time in the Soviet system. The latter approach offers a much richer source of examples for ethical analysis and discussion.

Looking at Chernobyl in this broader context, there are many possibilities for analyzing ethical decision-making at various levels of responsibility and involvement with the actual incident. In addition, as one reads the literature, there is a good deal of finger-pointing that goes on amongst various key players. Again, there is plenty of blame to go around and where the ultimate blame lies is debatable. Good arguments can be made for blaming the technicians directly, the management that was charged with running the plant and the test, or the Soviet system that encouraged the plant to be put into operation before it met established safety standards. It could even be argued that the flawed Reaktor-Bolshoy-Moshchnosti-Kanalniy (RBMK) design itself was to blame, so building a plant based on that design should never been sanctioned.

All of this suggested to the author the idea of assigning students to take on the role of one of the factions (or stakeholders) in the debate. Students are divided into groups and tasked with defending the decisions and actions of one of the following factions:

1. *The State*—The elements of the Soviet government with direct or indirect oversight of the nuclear power program and therefore Chernobyl. This includes the Ministry of Atomic Power Stations, the State Committee for Safety in the Atomic Power Industry and the whole framework of the Soviet bureaucracy at the highest levels.
2. *The Plant*—The Director of the Chernobyl Station, Viktor Bryukhanov, and other elements of the station management.
3. *The Reactor*–The crew of the reactor itself, including Chief Engineer Nikolai Fomin.

The group assignment then consists of four parts. First, students must research the incident itself and craft a defense of their faction based on appeals to the National Society of Professional Engineers (NSPE) code of ethics and ethical theories of decision-making. This implicitly includes a criticism of the other two factions according to the same criteria so this is also explicitly required. Second, students must write up a summary of their research and arguments citing references. The third piece is an oral presentation by the group based on their written summary and the final component is an informal debate and discussion with the other groups.

The introduction to the project takes place during a weekly lab session near the middle of the semester. This introduction also includes the brief review of ethics mentioned above. Students are then given approximately three and a half weeks to complete their research and submit their written summary. The instructor then has a few days to read their summaries before the lab session where the oral presentations and debate occur. From the time their written summary is due, groups have about 4 days to prepare their presentation. In this time, they are also asked to prepare at least two questions for each of the other two groups. Each group makes their presentation and then fields questions from the other two groups. When the presentations and debates are finished, the instructor leads the class in a discussion. This final discussion is free-form and addresses the quality of various arguments, asks students to think about points that were (or were not) raised, and allows any remaining questions or concerns they might have to be discussed. This discussion serves as a debriefing, has no adversarial character, and allows students to voice their own opinions and points of view about various arguments instead of the ones they were assigned. Since the issues surrounding Chernobyl are complex and there is so much blame to go around, this discussion necessarily leads students to conclude that there are often no easy answers to ethical problems.

Assessment

Rubrics are used to score the oral presentations and written summaries. Both of these rubrics are slightly modified versions that have been borrowed from outside sources. Neither is considered completely satisfactory, especially since the oral presentation rubric does not adequately assess the debate portion of the assignment. Rubric scores translate directly into student grades and, overall, student performance is at or above expectations. Students have plenty of experience writing reports and giving presentations by this time, so their performance related to these mechanical aspects has been acceptable.

It has been the author's experience that students very much enjoy the debate portion of the assignment. Groups become vested in their faction and even the most taciturn students tend to vigorously participate in the debate. A healthy sense of competition arises, with students seeking to think of questions that will catch the other groups off-guard and to adequately prepare a defense for any and all criticisms of their own faction. When this assignment was first tried in the spring of 2009, the ensuing debate and discussion suggested that there was something special going on and it led the author to repeat the assignment in 2010 and 2011.

There have been problems with the assignment as well though. The degree to which students have applied ethical theories to their arguments has never seemed satisfactory. In almost every case, groups have typically lost points on their written and oral summaries due to a lack of depth in the context of ethical arguments. Also, enthusiasm for debate does not necessarily imply that learning is taking place related to moral reasoning. It became obvious that some other benchmark was needed to assess the degree to which students were (or were not) improving their moral reasoning ability.

Student Surveys

Starting with the first iteration of this assignment, students were asked to fill out an anonymous survey. One of the original purposes of the survey was to confirm the student enthusiasm that had been observed anecdotally. Students were also asked to gauge the degree to which the assignment increased their understanding of ethics and developed their skills related to research, communication and teamwork. In retrospect, the survey was not a very good tool for assessing the degree to which ethical reasoning was improved but it did produce some useful information.

The first portion of the survey was a series of affirmative statements about the assignment. Students could choose the degree to which they agreed or disagreed with each statement. It is the author's belief that these types of questions often result in a response bias, with students tending to answer in the way they think they are expected to. In fact, not a single student who completed the survey responded with Disagree or Strongly Disagree to any of the statements that were presented. With this in mind, the only results that stand out are those for which some students gave a response of Neutral/No Opinion or those for which there was a high percentage (at least 2/3) of strong agreement.

Overall students strongly agreed with the following statements: the assignment was interesting, it increased their understanding of ethics, they were given sufficient background, and they could see the relevance to their education as engineers. Students had less positive feelings about how well the assignment developed their teamwork skills and what exactly they were expected to learn.

The second portion of the survey asked open-ended questions about the assignment: Did the assignment increase their understanding of engineering ethics beyond what they'd seen before? Did they enjoy the project? What part did they like best? How could it be improved? Students unanimously identified the debate as the aspect they enjoyed most. The suggestions for improvement were: the ability to choose their own faction, a more structured debate environment, and a more detailed definition of the factions. The first two suggestions have already been incorporated. Groups now have an opportunity to choose their faction but of course this is a first-come-first-serve process so there will always remain the possibility that some students are unhappy with their faction. The submission of group questions and an orderly procedure for posing them has given the debate more structure. What started out as something of a free-for-all now proceeds in an orderly fashion with thoughtful questions followed by responses. In the next iteration, an effort will be made to better define the factions. In their research, some students expressed confusion as to which faction certain players should be assigned to. For example, a few students expressed doubt about Nikolai Fomin's placement in Faction 3 rather than Faction 2. The issue of faction definitions will be revisited in the future, but they have worked pretty well for three iterations of the project.

On the survey, students also unanimously believed that the project had increased their understanding of engineering ethics, but their reasons for believing this are nebulous. Students used phrases like "going into more depth", "being much more involved", "enhancing what we already knew", and "asking the important questions". Coupled with the apparent confusion by some students about what they were supposed to be learning, these results suggested that a better tool was needed to assess their understanding of ethics.

The ESIT

In recent years the second version of the Defining Issues Test (DIT-2) has been an accepted choice for assessment of ethics instruction (e.g., Drake et al. 2005). The DIT-2 is administered as a pre-test and post-test to assess the effect of instruction on moving students from pre-conventional to post-conventional moral reasoning. The DIT-2 is based on a refinement of Kohlberg's schemata for moral development (Rest 1999, Crain 2011) and its validity is well-established (Rest et al. 1999). The DIT-2 is easy to administer but must be ordered and returned to the authors for scoring. Costs include the printing of the test and answer sheets as well as the scoring service itself. The Engineering and Science Issues Test (ESIT) is a more recent assessment tool that is modeled after the DIT-2. The ESIT is aimed specifically at engineering and science students, involves no costs, and includes instructions that allow it to be easily scored by the user. Given these advantages, the author chose to administer the ESIT to Modern Physics students as a pre-test and post-test to assess the effect of the Chernobyl case study and debate.

The ESIT asks students to analyze six ethical dilemmas and rate the importance of twelve issues for each of them. The twelve issues are a mixture of pre-conventional, conventional, and post-conventional thinking along with some nonsense issues. Students then choose the four issues they feel are most important to the resolution of the dilemma. The students' P scores are calculated based on how many post-conventional issues they choose as one of the four most important for each dilemma. The P score is an indicator of the amount of post-conventional reasoning applied by students and is almost identical to the P score used for decades with the original DIT (Rest et al. 1997). The N2 score was developed for the DIT-2 and is the key measure of changes in moral reasoning for the ESIT. It not only measures the extent to which post-conventional reasoning is present but also the extent to which pre-conventional reasoning is absent. Averages are calculated for the students' responses to all post-conventional and pre-conventional issues for all six dilemmas. A scaled difference between these averages is then added to the P score to generate the N2 index.

Summary of ESIT Demographic Information

The ESIT was administered to students as a written pre-test and post-test in Modern Physics during the spring 2011 semester. Students were not required to take the tests and received no credit or penalty for either taking it or not taking it. The participants represent 9 out of the 10 students who took the course. One student failed to complete the ESIT before the start of the project and was subsequently not involved in the post-test. None of the submissions met the criteria established by the authors of the ESIT for being discarded (Borenstein et al. 2010).

All of the students were sophomore engineering majors aged 19–21 except student #9. Student #9 was a 22 year old senior science-education major whose relevant course history was identical to the other 8 students. Students #3 and #6 were non-native English speakers from mainland China; all other students were US residents. Student #5 was the only female in the study. All students indicated having "some ethics content in other courses" and "no significant employment in a technical position". In their political views, six students identified themselves as "somewhat liberal", two marked "somewhat conservative" and two marked "neither liberal nor conservative". Four students considered themselves spiritual with no participation in organized religion, three participated in religious activities at least once a month, one participated in religious activities at least once a year, and one student did not consider himself spiritual.

Summary of ESIT Results

The average increase in N2 scores was 1.03, indicating that there was a shift from pre-conventional to post-conventional moral reasoning overall (Table 1). It is interesting to note that Students 3 and 6 experienced a net decrease in their N2 scores and they were the only non-native English speakers in the class. Published

Table 1 Pre- and post-test P and N2 scores

Student	Pre-test P Score	Post-test P Score	Pre-test N2 Score	Post-test N2 Score	N2 score diff
1	0.65	0.72	5.11	5.28	+0.17
2	0.57	0.62	3.67	5.48	+1.81
3	0.48	0.33	1.19	-1.07	-2.26
4	0.27	0.50	0.27	2.88	+2.61
5	0.43	0.45	3.09	4.65	+1.59
6	0.43	0.42	2.07	0.74	-1.33
7	0.38	0.68	0.95	4.26	+3.31
8	0.43	0.60	1.93	4.16	+2.23
9	0.53	0.48	1.38	2.55	+1.17

results for the ESIT showed no significant change in N2 scores for non-native English speakers. This study shows a marked decrease in N2 scores for the non-native English speaking students. There are several possible reasons for this, including the language barrier and cultural issues, but it is still surprising that these students experienced such a marked decrease in their N2 scores (Table 1).

Aside from non-native English speakers, every student showed an improved N2 score. Even students whose initial N2 score was relatively high showed some improvement. This is an encouraging result, especially given that there was no formal ethics instruction taking place. The ESIT was originally assessed for students receiving a semester of formal ethics instruction, so one might expect that a single project like this would see modest gains at best or no significant change at all. The fact that each of these students experienced at least some improvement in moral reasoning suggests that the project is having an impact.

The sign test and the Wilcoxon signed-rank test were both performed on the pre-test and post-test N2 scores. The sign test ($P = 0.18$) and the signed-rank test ($W = 10$, $0.10 < P < 0.20$) both indicate that the change in N2 scores is not significant when all the student data is used. If the results for the non-native English speakers is excluded, the sign test ($P = 0.016$) and the signed-rank test ($W = 0$, $P < 0.016$) both indicate that the increase in N2 scores is significant. The results for the non-native English speaking students are markedly different from the others but excluding them may or may not be justified. Unfortunately, the ESIT wasn't scored until after students had left for the summer. Future investigation (if possible) might reveal if these two students just scored poorly or if their scores reflect some difficulty posed by the language barrier or cultural differences. This issue also shows up in analyses of the DIT-2 (Rest et al. 1999) and the foundational study for the ESIT (Borenstein et al. 2010).

Discussion

The importance of ethics education to engineers is not disputed but the literature is filled with suggestions about how best to accomplish the task. There are criticisms leveled at certain methods and suggestions about the aim of ethics education that should be addressed.

Criticisms from the Literature

Harris et al. (1996) suggested case studies involving big disasters should be avoided because students tend to think of these events as something that happens to someone else. Other authors have taken a similar approach by creating case studies involving situations they feel students can better relate to, such as academic dishonesty (Vesilind 1996), billing and client/employer relations (Santi 2000), or treating ethical dilemmas like design problems (Bero and Kuhlman 2010). The Chernobyl project may be a "big disaster" scenario but the role-play aspect forces students to put themselves in the shoes of decision makers and defend their actions. The enthusiasm with which they argue for their faction—and against the others—suggests that it becomes very relevant to them. An approach like the one presented in this paper may be a good way to treat "big disaster" scenarios when it is desirous to do so.

Drake et al. (2005) provide evidence that an embedded ethics module is not an effective method to increase moral reasoning according to the DIT-2. Their definition of a module is two class periods of formal instruction in ethics, two short case studies in class, and one case study completed by groups in lab. The assignment described in this study is a larger project overall and it is completed entirely by groups of students. The inclusion of the role-play and debate aspects is also distinctive. For these reasons, the conclusions of the Drake study probably do not apply to the Chernobyl project. Having used the ESIT as a metric, it may not be fair to directly compare the two studies. Also, the number of students in this study is small so further data is warranted before claiming that the Chernobyl project contradicts the conclusions by Drake et al.

It has long been known that constructive controversy gives superior results compared to pure debate, individualistic learning (Johnson and Johnson 1985), or concurrence-seeking (Smith et al. 1981; Mitchell et al. 2002). The Chernobyl project was not presented as a constructive controversy per se and it does not include explicit instructions for students to argue one point of view and then argue an opposing point of view. But the students are asked to consider all points of view and adequately prepare for counter-arguments. So, in this sense, it is not so different from some published examples of the method where students are given little or no time to consider the second point of view and the synthesis occurs in a class discussion or "debriefing" (e.g., D'Eon and Proctor 2001 or Wareham et al. 2006). The debate portion has always been good-natured and participation has been 100%, so it appears that an atmosphere where students feel free to contribute has been maintained.

Suggestions from the Literature

Some recent studies take a broad look at current practice in engineering ethics education. There are implications here for what is wrong with current efforts and suggestions for improvement. To the degree that the Chernobyl assignment is relevant to these discussions, it holds up very well.

Newberry (2004) identifies several areas where ethics education could use improvement. He states that engineering students often find ethics to be boring and unimportant. Students also perceive ethics to be less important when it is "squeezed into" the midst of technical material. He suggests that some of this may arise from faculty with no background in ethics and whose attitude about ethics derives from a technical background which placed no importance on it. He further suggests that the current environment in academia places no value on faculty acquiring such a background.

From the surveys mentioned above and from personal experience, it is clear that students find the Chernobyl project to be anything but boring. As mentioned, this project is not a case of ethics being "squeezed into" the curriculum. Every effort has been made to show how these ethical issues arise naturally from the application of technical expertise to real world problems. On the issue of faculty background, the author would point out that their background not only lacked a formal ethics component but also was not in engineering. Newberry suggests that the efforts of the average engineering faculty to teach ethics have been less than stellar. The author would submit that what is "average" must change with evolving ABET standards and that engineers are ideally suited to the challenge. Faced with implementing a new engineering program in what had been a physics department, the faculty at <Author's Institution> is working hard to adapt and acquire the requisite knowledge. If the engineering community puts a premium on ethics education, then there is no choice but to evolve or outsource the responsibility. It is hoped that this paper will play a small role in supporting that evolution.

Colby and Sullivan (2008) make several helpful suggestions based on a survey of ethics instruction at a number of U.S. engineering programs. First, they suggest using ethics codes as a framework to more broadly define ethics and professional responsibility. This project fits well with that goal in several senses. The factions are not limited to engineers and engineering practice; students have to consider a broader range of ethical decision-making than simply the engineers in the control room that night. While students have been familiarized with the current form of the NSPE ethics code, it is also true that ethical codes evolve over time and may be tempered by societal rules. This project requires students to consider ethical reasoning in the unusual context of the Soviet era, where personal well-being quite often ran up against professional responsibility in a political system that could often be quite brutal and unforgiving. Students are faced with ethical dilemmas that seem familiar—like whistle-blowing—but the decisions have to be considered within the broader societal context in which the players found themselves. There is often more at stake than losing a job and the role-play and debate aspects require students to really grapple with these issues.

Colby and Sullivan also suggest incorporating ethics instruction into "complex tasks that require technical skills, interpersonal capacities and multiple dimensions of ethics and professional responsibility." The recommendation here seems to be closely related to a favorable view of service learning projects. The Chernobyl project is incorporated well within material that requires a certain level of technical mastery. Students must become familiar with the design and operation of the RBMK reactor to understand the technical issues that led to the accident. In addition, the project has been used for the last 2 years as a springboard for a subsequent design problem. In the first case, students were asked to identify the design flaws in the RBMK reactor and research the way those flaws were eliminated in subsequent designs. Most recently, the Fukushima disaster was unfolding during the time the course was being taught. After the completion of the Chernobyl project, students were asked to design an alternative cooling system for the storage pools that addressed some of the problems the Fukushima engineers were facing. "Interpersonal capacities" are well addressed by the group nature of the project and the debate itself. Finally, as mentioned above, in this project students are indeed asked to consider "multiple dimensions of ethics and professional responsibility." So, while not a service learning project, this assignment does incorporate most of the outlined suggestions.

The last three suggestions by Colby and Sullivan include promoting active pedagogies, faculty enthusiasm and an institutional involvement that fosters ethical development in an intentional way. The first of these suggestions really refers to emphasizing ethics in contexts where students are actually practicing engineering, like internships, service learning or even senior projects. Being a classroom assignment, this project could not be considered an "active pedagogy" in this sense. But, by asking students to take on a role and actively engage in debate, it could be said to be a more active pedagogy than reading a case study and formulating a response to a question or dilemma. The other two suggestions—instructor enthusiasm and institutional commitment to ethics instruction—are really beyond the scope of this paper. It's unclear how one would quantify or qualify instructor enthusiasm but the author believes the observed level of student enthusiasm and participation attests to this to some degree. As to the last point, <Author's Institution> is a private liberal arts university with a long tradition of fostering the ethical development of its students. Since Colby and Sullivan have indicated that this seems to have a positive impact on ethics education efforts, this may have also played some role in the positive results that were observed.

Future Efforts

Moving forward, attention will be focused on improving the project, improving the assessment tools and accumulating more data. It is hoped that such data will play a small role in helping the authors of the ESIT to confirm its validity and limitations. The anomalous results for non-native English speakers is a topic worth pursuing since it shows up in this study as well as the original work that established the ESIT. Since the percentage of non-native English speakers is steadily increasing at <Author's Institution>, the author intends to devote some effort to understanding these results as well as ways to improve assessing ethics instruction for these students. Interviewing non-native English speakers who have completed the ESIT may provide insight and an attempt to translate the ESIT into the students' native language may prove beneficial.

Conclusion

This paper describes an approach to treating the case study in engineering ethics using role-play and constructive controversy. Student feedback indicates a high level of student enthusiasm, interest and satisfaction. The results of the ESIT for native English speakers are encouraging and suggest an improvement in students' progress from pre-conventional to post-conventional moral reasoning. This improvement is surprising since the method involved no formal instruction in ethics or guided analysis of other case studies and occurred amongst students with only a modest background in engineering ethics. Since the sample size was so small, more data is needed to make any definitive conclusions regarding the N2 scores on the ESIT but the results seem consistent with the tool's foundational study. This approach stands up favorably to the criticisms leveled at ethics instruction in engineering education and also to the suggestions for its improvement. It is firmly embedded in the curriculum and draws on a host of skills deemed essential for engineering students. The author welcomes any inquiries about the method and would be happy to share whatever resources might be of interest.

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