SUSTAINING ETHICS EDUCATION IN ENGINEERING: A BLENDED APPROACH TO ETHICS INSTRUCTION

Interactive Qualifying Project Report completed in partial fulfillment of the Bachelor of Science degree at

WORCESTER POLYTECHNIC INSTITUTE

By

John Hobson, Wasih Kamran, Zack McKinzie, and Dylan Renshaw

2015

Submitted to

Professor Kristen L. Billiar, PhD

Professor Geoffrey Pfeifer, PhD

Abstract:

Engineering educators face challenges when it comes to teaching ethics, such as a lack of training in ethics instruction and difficulty finding time to fit in ethics alongside the entirety of the engineering coursework. Results from previous projects indicate that a joint-venture approach, where humanities professors provide ethics lectures in engineering courses, is a viable method for improving ethical reasoning for engineering students. Yet implementing these lectures requires humanities professors to volunteer to do extra work above their normal teaching load, and takes class time from technical content. The aim of this project was to develop and implement a sustainable blended online method for instructing students in how to recognize and navigate ethically unclear situations with short in-class discussions and to compare this method with full in-class lectures from trained faculty. In order to determine the effectiveness of the blended online method, it was tested against a joint-venture control. The blended method was composed of two parts: an online module comprised of a video series featuring trained ethics instructors and an in-class discussion led by the regular professor. Students were surveyed before and after the methods were implemented. Out of the six questions asked on the post-survey, two could not be proven to be statistically different between the two methods and four questions were shown to be statistically different in favor of the blended method, supporting the claim that the blended online approach can be a sustainable and effective educational method. With a more widespread and integrated approach this method could be used for more than an introduction to ethics, with modules specifically designed to cover ethical issues to a greater extent.

Acknowledgements

The IQP team would like to thank Professors Kristen Billiar and Geoffrey Pfeifer for their continued support throughout the duration of this project. We'd also like to thank Professors John Sanbonmatsu and Paul Kirby for assisting in teaching ethics in online and in class formats, as well as professors David DiBiasio, Nikolaos Kazantzis, Nicholas Bertozzi, Craig Putnam, Dirk Albrecht, William Michalson, Joseph Stabile and Amanda Reidinger for allowing us to implement our educational methods into their classes. We would also like to thank Sophia Jagannathan of the ATC and Rebecca Ziino of the Gordon Library for helping us with technical and research issues we came across. We would also like to acknowledge Marty Fitzgerald in helping coordinate the discussion in the CHE 2012 class.

Authorship Page

Each student contributed equally to this Interactive Qualifying Project.

Abstract - Zack McKinzie
Executive Summary - John Hobson, Dylan Renshaw, Wasih Kamran
Introduction - John Hobson, Wasih Kamran, Zack McKinzie, Dylan Renshaw
Literature Review
-The Need for Engineering Students to Learn Ethics - John Hobson
-**Teaching Ethics as a Standalone Course** - Wasih Kamran
-Teaching Ethics Across a Curriculum – Wasih Kamran
-**Using Case Studies to Teach Ethics** - John Hobson
-**Using Joint Ventures to Teach Ethics in the Classroom** - Wasih Kamran
-**Online Education as a Method of Teaching Ethics** - Wasih Kamran
Methodology - Zack McKinzie, Dylan Renshaw, Wasih Kamran
Results - Dylan Renshaw, Zack McKinzie
Discussion - Zack McKinzie,Wasih Kamran, John Hobson
Future Recommendations - John Hobson, Wasih Kamran, Zack McKinzie
Conclusion - John Hobson, Wasih Kamran

Table of Contents

Executive Summary

Introduction: Engineers must be prepared for ethical situations that will arise in the workplace and they must be able to figure out what is the best decision. Engineering students must learn ethics while in college in order to have the tools necessary to handle ethical dilemmas. However, many engineering students are not educated to deal with ethical situations because engineering ethics is not emphasized enough at many engineering universities. Even in the engineering courses that students take many professors do not have the proper training to teach ethics to students. Last year's project came up with a method of using philosophy professors to teach ethics to an engineering class to teach students how to handle an ethical dilemma. This project came up with a blended approach to guide students through an ethical problem, where students learn ethical material from philosophy professors in online videos and then discuss a case study with the regular instructor of the engineering class. This method was set up to be sustainable, consistent, and scalable for educating various engineering classes.

Methodology: The blended approach was implemented into two sophomore and junior classes. Students learned ethics material through three online videos from three philosophy professors and read a case study that was related to their major. They also answered pre-survey questions to see what background the students had in ethics. Students then discussed the case study in class with the native professor facilitating the discussion. Students after class answered questions about the case study to see if they could handle a particular ethical situation. Then the students answered a post-survey to see if they liked this ethics module as well as see if they were confident in dealing with an ethical dilemma. The joint-venture method that last year's project

used was also incorporated into four sophomore and junior classes as a control that would be compared to the blended approach. This comparison was done to see if the blended approach was as effective in teaching engineering students ethics as the joint-venture method. The results were compared using a test for two independent samples with dichotomous outcomes (success versus failure).

Results: Classes that were given extra credit had a participation rate over 90% for the pre-survey, and over 65% for the post-survey, which is enough to accurately represent the student populations. One class did not receive extra credit for the ethics modules, which resulted in participation rates of 74% for the pre-survey and 22% for the post-survey. These low response rates resulted in a non-response error, so the class was removed from data analysis. Of those students who responded to the pre-survey, only 14% of them have taken an ethics dedicated course, even though 4 courses are offered at WPI. In addition, 74% of students either agreed or disagreed with 9 statements claiming ethical competence and understanding, while only 5% disagreed or strongly disagreed. After the ethics module was completed, the post survey was answered. Of the 6 questions on ethical competence and future exposure, only 2 could be shown to be statistically different between the two methods, which was in the favor of the blended approach, while the results of the other questions could not be shown to be different. This indicates that the blended method is as effective, if not better, than the joint-venture approach in regards to interest and learning for the sampled students.

Discussion: The blended approach addressed some of the key drawbacks of the joint-venture model that was also tested. In addition to being a more sustainable and scalable approach (assigning videos to classes were more consistent than dealing with joint-venture preparations), it also proved to be as effective in teaching students about engineering ethics through the analysis of student survey responses. Only two survey questions were found to be statistically different in favor of the blended approach, while the rest of the questions could not be shown to be statistically different between the two methods. In addition to addressing joint-venture drawbacks and being a comparable method in effectiveness, the blended approach also improved on some limitations of online education that were outlined in the literature. The approach still had an in-class discussion component, allowing students to have an avenue for voicing their opinions and understanding other points of view as well. The videos themselves also had discussions between three philosophy professors, displaying to students that ethics is not always concrete and that differing opinions exist between people in the philosophy field as well.

Recommendations: The blended approach was an effective tool in teaching students ethics, but there are still enhancements that need to be made to better teach students ethics as well as implement it on a larger scale. Students in their feedback said that they learned ethics from the videos, but said that they were boring. The videos need to have greater production in order to make the videos appealing to students, which will make them more interested in learning ethics. Another recommendation is to implement these online videos across all the engineering fields at WPI so that many engineering students have the ability to handle ethical dilemmas in the workplace. A greater implementation of these online videos will show engineering students how there is a connection between ethics and the engineering course work. There should also be improvements to the way in which to measure the impact each method had on students' learning.

Both methods had students fill out surveys to test their aptitude in ethics, but their answers only show if they gained an understanding of ethics as well as well as confidence. This team suggests giving the students a small assessment that they must take to see if they learned their ethics material as well as if they can handle an ethical situation. These tests will give tangible evidence about students' knowledge in ethics and not just their opinion on their capability. The tests will also give more accurate results on the effectiveness of a particular method.

Conclusion: Engineering ethics is not emphasized enough at WPI, which is important because engineering students will encounter various ethical dilemmas in the professional world. There are ethics courses offered to students, but are not required to take one. This IQP has been tackling these problems at WPI, with last year's IQP coming up with a joint-venture method. This method was effective in teaching students ethics, but is not sustainable and consistent. This IQP came up with a blended approach to deal with these drawbacks and implemented it into engineering classes to see if it can be as impactful in teaching students ethics as the joint-venture. After collecting data, this IQP found out that the blended approach was as effective in educating students in ethics as the joint-venture.

I. <u>Introduction</u>

An understanding of ethical duty and responsibility is essential for an engineer of any profession. Oftentimes the media will report on the failure of engineers to act morally when faced with a major dilemma, but these massive media cases are far from the norm. Engineers face all sorts of ethical issues in their everyday lives, like the impact their work might have on the environment. Unfortunately, many engineers are unable to recognize and navigate minor ethical uncertainties that they will regularly face due to a lack of collegiate instruction (Bird and Sieber, 2005).

It is important that engineers are able to recognize these uncertainties because the decisions engineers make are critically important. Sometimes they might even have to go against the company they work for in order to make the right choice. For example, Salvador Castro, a medical electronic engineer at the incubator making company Air-Shields Incorporated, found a design flaw in an infant incubator and proceeded to tell his supervisor about it. The company did not spend the money to fix the problem and Castro ended up getting fired when he threatened to let the Food and Drug Administration know about this flaw (Kumagai, 2004).

Not all ethical decisions engineers have to make are as obvious as the one that Castro encountered. Robotics engineers who build robots for service and healthcare jobs must think about the lack of human interaction as a direct consequence of their work. For example, when creating a robot responsible for taking care of the elderly, engineers have to take into account the ethical dilemma of depriving the patients of human contact (Billard, Kahn, Łichocki, 2011).

A majority of the decisions engineers will make will not require them to know what is right or wrong; rather, they will need the necessary education to carefully navigate situations that may not be as easy to understand or identify. In order to prepare engineering students for the ethical dilemmas that might occur in the workplace, students should be educated in engineering ethics while they are undergraduates. This need for undergraduate ethics education was driven home when the Accreditation Board for Engineering and Technology (ABET) created a criterion in 2000 that universities must include ethics in their engineering curriculum (Rabins, 1998). ABET is an organization that sets educational standards for collegiate science, engineering, and computing programs across the United States. The criterion includes the requirement that students have the knowledge to be professionally and ethically responsible (Rabins, 1998). ABET established this criterion because of the reaction of scientists and engineers to major incidents of wrongdoing, which have caused great concern amongst the public (Bird and Sieber, 2005). Knowing that these standards exist for engineering students, it is important that schools emphasize ethics and try to incorporate them into engineering courses.

Even with the ABET standards that are in place, engineering ethics is not emphasized enough at many universities because they do not have enough engineering professors who are trained in teaching ethics (Bird and Sieber, 2005). According to Frey and Cruz, there is a lack of instructors who have the qualifications necessary to teach an engineering ethics course (2003). The lack of engineering professors trained in ethics is exemplified by the situation at the University of Puerto Rico at Mayagüez. In 2003, a course on engineering ethics was made available to students of the University of Puerto Rico as a free elective. If this course had been mandatory, however, there would not have been enough trained faculty to teach all the engineering students (Frey and Cruz, 2003). The University of Puerto Rico exemplifies a university where there are not enough trained engineering instructors that can teach students ethics, leaving many of the students without this important subject. In addition, it is hard for faculty to teach engineering ethics because many of them do not have a background in ethics (Bird and Sieber, 2005). They also have so much information they need to cover in their courses that it makes it difficult to implement additional material in a class (Frey and Cruz, 2003). This lack of ability of the faculty to adequately teach ethics makes it an obstacle in implementing ethics education in engineering departments.

Previously, an Interactive Qualifying Project team suggested that the best method to combat this inadequacy was through a joint-venture approach where a philosophy professor would volunteer to lecture in an engineering class (Jackson, Jasensky, Liang, Moore and Rogers 2015). The lectures were broadly based on professional ethics however the specific content was up to the lecturer's discretion. All lectures contained relevant case studies that were discussed in class and assigned with questions for the students to finish. Out of 203 students that replied to last year's IQP team's surveys, nearly 85% wanted to incorporate a similar method of ethics education in their future classes. The group received positive feedback from both philosophy professors and students; however, their study had some limitations. The study was limited to biomedical engineering classes and purely relied on philosophy professors volunteering their time to participate in the guest lectures, as well as engineering professors volunteering full lectures in their classes. The main recommendations the team made was that the guest lectures needed to be more consistent from year to year and that the incorporation of ethics education needed to be across the entirety of a student's time at WPI, not just in one class (Jackson, Jasensky, Liang, Moore and Rogers 2015).

The goal of this IQP is to develop a sustainable, more consistent, and scalable model that can educate students about engineering ethics as effectively as the previously proposed joint-venture method. Our team's aim is to do this by testing the viability of a blended ethics module in WPI's engineering curriculum through several sample classes.

Our proposed educational method is a blended ethics module using videos featuring WPI philosophy professors. These videos are solely dedicated to introducing ethical concepts and demonstrating how to analyze ethical issues. The students will also read a case study that is relevant to that engineering field to give them an understanding of the ethical dilemmas they might face in the professional world. This will be followed by an in-class discussion about the case study they read. This discussion will be led by the students' regular engineering instructor. A blended model was chosen because studies have shown that having interactive discussions are an integral part in ethics education (Bird and Sieber, 2005). This model would be tested against the aforementioned joint-venture method where a philosophy professor would come in as a guest lecturer in several engineering classes. We have hypothesized that this blended method could be effective in providing students with knowledge of ethics in their respective fields and increase awareness of ethics in their profession as well as the previously introduced joint-venture approach.

II. <u>Literature Review</u>

2.1 The Need for Engineering Students to Learn Ethics

Ethics codes were first established in engineering fields in the early 1900's (Colby and Sullivan, 2008). Since then several engineering fields have established codes that engineers must follow (Colby and Sullivan, 2008). With the codes of ethics in many engineering fields and the standards set by ABET for universities, ethics needs to be emphasized in the engineering curriculum, as students have to be prepared to make ethical decisions in their careers. The need to teach ethics to engineering students can be seen in a study conducted by Wang which showed, over 90 percent of engineering students lack the knowledge of ethics in engineering (Wang, 2011).

Engineering students must learn ethics in order to be prepared for professional engineering, as they will have to confront situations that will test their morality (van de Poel and Smuga-Fries, 2015) also mentions how engineers are problem solvers and have the mentality that there is a right or wrong answer when they are making decisions. Most engineers by nature think black and white and only later on question if they made the right choice (Van de Poel and Smuga-Fries, 2015). Because of this way of thinking, Van de Poel stresses that they must learn to be more like philosophers who ask questions when they are making decisions. It is important that engineers ask the proper questions even if they have not found an answer (van de Poel and Smuga-Fries, 2015). Given that many engineering students have this concrete way of thinking, they need to be trained in ethics, which will cause them to question the world around them. This will help them deal with situations where the right answer in not obvious.

Engineering students need to learn ethics in order to consider the impact their decisions will have on society. Engineering fields have common goals for ethics that it is important for engineering students to consider the effects of their decisions on public safety (Colby and Sullivan, 2008). Engineers cannot just look at the technical side of engineering, but have a moral obligation to ensure the protection of the community. Engineers must understand that their decisions can have major effects on society and the world. Colby and Sullivan explain that the work engineers do have repercussions for the environment and society as a whole and they need to be accountable for the impact their work has. (Colby and Sullivan, 2008). Engineering students must comprehend that there is an ethical viewpoint to consider in engineering, which includes the idea of the engineer as a citizen. This shows how important the need for ethics teaching is in engineering schools.

2.2 Teaching Ethics as a Standalone Course

Perhaps the most common method of educating prospective engineers on ethics is developing a standalone course taught by a single philosophy professor. This method provides a dedicated platform for discussions predicated solely on ethics without the inclusion of technical instruction. The main advantage of this method is that strictly students interested in learning ethics would be in the class; this would increase active participation in discussions and result in overall better class quality (Li and Fu, 2012). The main drawback with this method is that it gives the impression that ethical considerations run outside of technical work and they are not constantly interconnected in the engineer's work (Zandvoort, Van Hasslet and Bonnet, 2008). One of the main goals of ethics engineering outlined by Zandvoort et. al emphasizes that ethics education has to consider the ethical implications of engineering with a wider scope than just the individual engineer. Having a standalone course on ethics hinders the student's ability to infer that ethics is an aspect of the entirety of engineering, not just the individual actions of individuals (Zandvoort, Van Hasslet and Bonnet, 2008).

2.3 Teaching Ethics Across Curriculum

Another method for teaching engineering ethics is to incorporate ethics into every class across the curriculum; instructors would essentially teach professional ethics alongside technical instruction every day. A daily integration of ethics alongside technical lessons would emphasize to students that ethics is an embedded topic of importance and not a standalone part of being an engineer. A continued emphasis on ethics throughout several classes would also provide appropriate contextual education and prevent a detachment of ethics from the technical subject matter of the course (Li and Fu, 2012). A key limitation of this approach is that virtually all engineering faculty would have to be trained to properly teach ethics in their classes. This is problematic because some engineering faculty lack ethical awareness themselves (Bird and Sieber, 2005). In fact, a study scoring engineering research articles with respect to how well they addressed the ethical obligations and social implications of the research found that engineering faculty scored poorly overall (Newberry, 2004).

2.4 Using Case Studies to Teach Ethics

Case studies are a common and effective way to teach ethics to engineering students. Case studies are effective because they give students a situation that will make them think about how to handle an ethical problem. According to Healy, case studies give a basic way of talking about ethical situations (Healy, 2000). In addition, case studies help give students a sense of what might happen when they are professional engineers. Rabins argues that cases need to stimulate the students' interests and initiate conversation about an ethical problem. When students read the case study they should be able to make connections to the actual engineering world (Panitz, 1995). In order to make case studies impactful, they must be done in a loose format where students brainstorm how to solve a problem (Panitz, 1995). This is important because engineers need to be able to come up with solutions to both technical and ethical problems.

Case studies are helpful because the class discussions that result from them can help students experience the different opinions that other students in the class may have on an issue. For example, Abraham and Abulencia have shown that case studies often have opposing issues in them. When students discuss these issues they can learn to think critically by listening to different opinions (Abraham and Abulencia, 2011). At Manhattan College, case studies were used in a lecture in an engineering course, which led to lively discussion containing a variety of opinions (Abraham and Abulencia, 2011). This study shows how case studies are an effective way to teach ethics to engineering students because it gets them involved in the class.

The "Online Ethics Center for Engineering and Science," is an excellent resource for instructors and engineering students to find different cases that involve ethical issues (Online Ethics Center, 2015). The online center has many topics under Case Studies where students can learn more about cases that involve subjects that deal with environmental issues and public welfare. These cases help students learn about the potential dilemmas they might encounter as professional engineers (Online Ethics Center, 2015).

As much as case studies are helpful for engineering students in learning about ethics, Healy believes that some case studies can be too obvious in their intention because they do not properly train students to handle more subtle problems that they will face in the workplace (Healy, 2000). Pritchard also argues that sometimes it is not always helpful in studying ethics because a majority of engineering students are not going to encounter extreme cases. They might not think that they have to worry about ethical dilemmas happening (Panitz, 1995). Therefore it is important for engineering students to study cases that they can relate to and that are relevant to what they will potentially face in the real world. This will help them be prepared for ethical situations in the workplace.

2.5 Using Joint-Ventures to Teach Ethics in the Classroom

The joint-venture approach to teaching ethics has been one of the three main strategies seen in most higher education institutions; the other two being the aforementioned standalone ethics classes and teaching ethics across all engineering classes. A joint-venture model involves multiple instructors teaching a single class in tandem. A proposed approach would be a lecture taught by a technical professor and a philosophy professor (Graber and Pionke, 2006). The class itself still uses common techniques such as case-based analysis. However, based on the group's hypothesis, the addition of a technical professor to the ethics discussion also provides real industry-related scenarios and experience to these discussions. Such methods emphasize the inclusion of ethics in daily technical decisions, rather than have ethics be an afterthought or standalone discipline (Li and Fu, 2012). The presence of a technical instructor can also introduce a code of ethics of the relevant discipline being taught that would not have been introduced with a philosophy professor teaching his/her own class (Zandvoort, Van Hasslet and Bonnet, 2008).

The limits of the joint-venture approach stem from a lack of a concrete system of integration in instructional curriculum. As of now, the system relies purely on motivated faculty that also have enough time to volunteer to come into other classes and teach (Zandvoort, Van Hasslet and Bonnet, 2008). Altruistic philosophy professors that would regularly volunteer their time are still not guaranteed to teach such lectures every year, seeing as they might be on sabbatical that term and thus cannot participate. Particularly with WPI and its emphasis on global education, professors would not always be available as they might be teaching in a foreign project center. In addition to philosophy instructors, the technical classes they would participate in also have very rigorous curriculums that result in very strict schedules that professors have to adhere to. Therefore, implementing ethics into those classes would pose a challenge to administering all of the technical aspects required of the course.

2.6 Online Education as a Method of Teaching Ethics

Online lectures have been found to be effective supplements of in person lectures in teaching core theories and laws (Wieling and Hoffman, 2010). The process of teaching ethics to an engineering class through an online approach is somewhat akin to the in-person joint-venture approach, as it requires a collaboration of multiple professionals from varying disciplines (Bird and Sieber, 2005). Like the joint-venture approach to teaching ethics, engineering professors still have to volunteer some of their class’s time in assigning the ethics material to students, the only difference would be that no lecture time would be affected in actual ethical instruction.

Philosophy professors would still have to volunteer their time teaching ethics, but they would be recording their lectures instead of talking to a live audience. Furthermore, technical experts would be needed to ensure that the videos are properly produced and distributed, something not needed in joint-venture techniques.

Although an online approach still requires collaboration between multiple people, the approach provides an avenue to circumvent some of the issues with the aforementioned traditional joint-venture model. The method provides a large degree of flexibility both from the end of the instructors as well as the student (Bird and Sieber, 2005). Philosophy instructors would be able to record and develop these modules when their schedule permits and technical professors would be able to implement the online content as they see fit without interfering with their rigid lecture schedules.

Where direct online lecturing breaks down is when discussions are involved; every group of students will discuss different aspects, explore different conversational routes and pose different arguments. It is integral that ethics discussions allow students to have novel discussions and communicate their arguments on ethical dilemmas (Bird and Sieber, 2005).

Another issue that arises with online teaching modules is low student participation and attentiveness. Students with a higher amount of motivation and self-efficacy tend to be more engaged and perform better in online components of classes (Roberts and Dyer, 2005). Therefore, it is imperative that students be properly compensated related to their grades to ensure participation and retention of anything taught online. Results from a previous iteration of this IQP indicated that student participation rate greatly dropped if participation was not incentivized.

Student participation average above 90% if they were offered bonus points or extra credit in the course hosting the experimental session. However, when students were not offered any incentive, participation plummeted to 44%. This drop in participation emphasizes the importance of motivating students to participate (Cantwell, Lam, Reyer, and Rafferty 2014).

III. Methodology

3.1 Restatement of Goal

The aim of this project was to assess the viability and sustainability of an online ethics module followed by an in-class discussion carried out by the regular professor of the course. The online module attempted to provide students with the ethical content needed to analyze an ethical situation. The students also read a case study online that was related to their field of engineering to give them a sense of what they might encounter in the workplace. The case study was then discussed the following day in class. The in-class discussion was a way for the students to express their thoughts on the case study while hearing the different viewpoints of other students and the perspective of their professor. This blended approach was intended to be more sustainable than having guest lecturers come in from the philosophy department to speak to these classes. The experiment utilized a number of paired classes from different engineering departments that had approximately the same number of students. One class experienced a lecture given by a humanities professor in the joint-venture approach, while the other class watched an online ethics module and then participated the following day in a discussion led by the primary professor of the class in the blended approach.

3.2 Current Means Assessment

Research was conducted into how ethics is being taught at WPI across a range of different programs that include Civil Engineering, Electrical Engineering, Aerospace Engineering, Robotics Engineering, Chemical Engineering, Mechanical Engineering and Biomedical Engineering. In addition to this research, data was also compiled from the

Registrar's Office showing the number of students who have participated in a variety of ethics-based courses currently offered at WPI. These humanity courses include PY 2713 Bioethics, PY/RE 2731 Introductory Ethics, PY/RE 3731 Problems in Ethics and Social Philosophy, and HU 224X Global Justice and Development.

Emails were sent out to each program head requesting information on who was in charge of ensuring their department met ABET requirements. One of the ABET requirements for maintaining accreditation is "an understanding of professional and ethical responsibilities" (Rabins, 1998). This mandated criterion had important ramifications for the IQP group's efforts in interdisciplinary engineering ethics education. Once the names and contact information for these ABET liaisons had been received, emails were sent to each program liaison requesting information on how ethics is currently taught in their department and if they believe it is well-implemented. This data was compiled and used to guide the selection of classes for implementation of the experiment.

To initially gauge the faculty's interest in devoting class time to ethics education, a simple survey was sent out that contained basic questions regarding the professor's interest in increased ethics education in their classroom as well as the method they preferred to implement. The professor was also asked how much time they would be willing to devote to teaching ethics and to identify the course registration number that would enable the team to contact them further.

3.3 Experimental Implementation

The experiment consisted of two groups: a control group participating in the joint-venture approach that received a guest lecture and discussion led by a philosophy professor and an experimental group participating in the blended approach that viewed a series of short online videos containing ethical content from philosophy professors, followed by an in-class discussion the next day led by their regular professor. The online lecture results were then compared against the in-class lecture results. For this experiment, all of the classes received a case study prior to having an in-class discussion. Both groups answered questions related to the case study they received in order to compare the learning comprehension of the students.

Before the classes received the case studies, students of each group received surveys that gauged how much exposure to ethics education these students have had in their academic careers, how much they valued learning ethics in class, and how they felt about it being taught in their engineering classes. The three groups also received a post-experimental survey that asked them questions about their thoughts on ethics, and how they felt about the means by which they learned ethics from this experiment.

The joint-venture lecture and the blended online method involved communicating and coordinating with many professors in different departments throughout WPI. A survey was sent out to professors to see if any of them were interested in incorporating ethics into their B-term classes. The professors that were willing to offer a full lecture period, usually fifty minutes, were found by using email to determine which method of implementation they preferred for their class. Once the essential number of classes was found in order to conduct the experiment properly, philosophy professors were contacted to see if they could volunteer their time for this project.

The joint-venture lecture first introduced basic ethical theories and moral obligations that the professor believed every engineer ought to have. The rest of the class was structured around a case study that was relevant to the engineering class being taught, with the guest professor from the philosophy department guiding the discussion and assisting with a point-counterpoint style that helped spark in-class discussion. The class was given a pre-experimental survey and a case study to read the day before the guest lecturer speaks. After this lecture, the case study questions were given to the students online to complete. Finally, a post-experimental survey was posted online for the class to fill out. This joint-venture lecture was intended to serve as the basis to compare the data that was gathered from last year's IQP team to the data collected this year. Once the students successfully completed both the pre- and post-surveys along with the case study responses, they were rewarded with extra credit in the class hosting the lecture (excluding ECE 2799). The exact amount of credit was determined by the regular professor of the class. The classes used for this group were BME 2210 (Biomedical Signals, Instruments and Measurements), ECE 2799 (Electrical and Computer Engineering Design), ES 3002 (Mass Transfer), and RBE 2001 (Unified Robotics I). The classes contained 117, 23, 65, and 37 students respectively, and were mostly comprised of sophomores.

The blended approach required the IQP team to recruit several philosophy professors who were willing to be filmed while they discussed the ethical topics that the IQP team and the advisors came up with. The IQP team filmed and then edited three online videos for the students involved in the blended experiment to view. The videos were filmed in a podcast-like format with three professors sitting in the center of the frame. The video was shot by one camera and recorded by one omnidirectional microphone rented from the WPI Academic Technology Center. The videos were then edited to include additional banners that elaborated on things being discussed in the videos.

The topics were similar to the ones taught by the joint-venture lecturer in the classroom. The first video focused on the importance of studying ethics as well as common ethical misconceptions that students have about this topic. The second outlined multiple ethical theories and discussed their advantages and disadvantages and the third video gave examples on how to apply ethical theories to professional and personal situations. Each video was 17- 22 minutes long.

The videos were posted to myWPI by the professor of the class for the students to view on their own time. The day before the videos were assigned, a pre-experimental survey was given at the end of class. The students were also instructed to read a chosen case study for their class after watching the video series, which was also posted on myWPI. The following day, the regular professor of the class led a short discussion about the case study and personal experience dealing with ethical dilemmas in the workplace, provided the professor had any such experiences. The professor then posted the case study that included questions for the students to fill out. The students were then instructed to fill out a post-experimental survey after every other aspect of the experiment was done in order to analyze the overall effectiveness of the video format relating to student interest and coherence. The classes used for this group were ES 2502 (Stress Analysis) and CHE 2012 (Elementary Chemical Processes). These classes were comprised of sophomores and juniors and contained 96 and 112 students respectively.

3.4 Data Analysis

Data from the two approaches were separated and compiled for analysis. The pre-experimental survey and post-experimental survey results were directly compared across the paired methods using a test for two independent samples with dichotomous outcomes (success/failure). To compare the two methods, a null hypothesis assumed that the data sets were equal for all questions, and p-values (from z values) were calculated for each question to determine whether or not the methods could be proven to be different within a 95% confidence rating. The equation for calculating the z values (**Equation 1**) is listed below:

$$Z = \frac{p1 - \mathrm{p2}}{\sqrt{p(1-p)(\frac{1}{n_1} + \frac{1}{n_2})}}$$

where p_1 is the proportion of successes in sample 1, p_2 is the proportion of successes in sample 2, and p is the proportion of successes in the pooled sample. Successes are defined as a “yes” response. P (in reference to population, not the p-value) is computed by summing all of the successes and dividing by the total sample size in **Equation 2**:

$$p = \frac{x_1 + x_2}{n_1 + n_2}$$

where x is the number of successes, and n is the number or responses.

IV. Results

Pre Ethics Module Survey:

The Electrical and Computer Engineering Design course was omitted from the results analysis as the participation for the course surveys was less than 25%, rendering the information unusable due to the non-response error. However, the rest of the classes' participation (see **Figure 1**) are representative of the majority of students. The results in the following sections will consist of the remaining three joint-venture classes, and two blended classes. The participation from the students in these courses was 88.96% for the pre-survey, covering 387 out of the 435 students in the classes, while the pre survey reached 80.23% of the students. The 435 students involved in this study make up approximately 1/10th of the undergraduate engineering students at WPI.

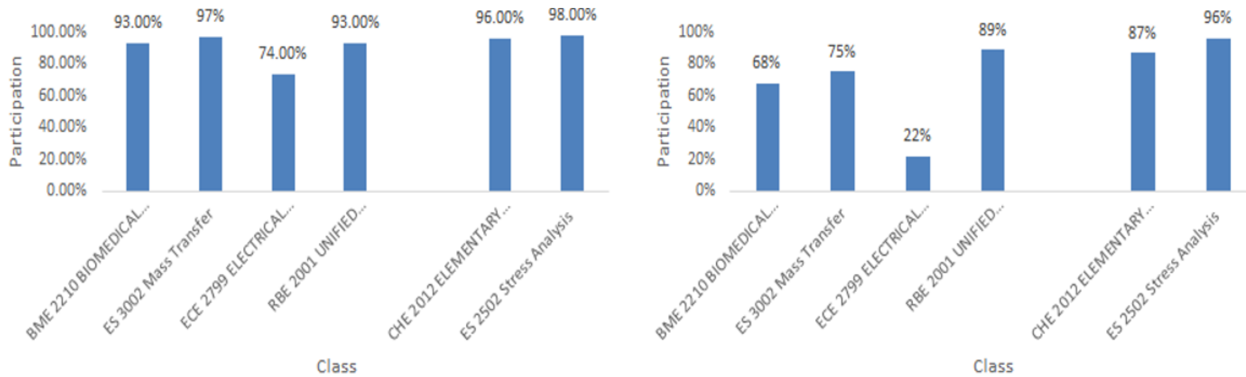

Figure 1: Pre survey participation (left) and post survey participation (right) for all classes.

Prior knowledge and ethical exposure for the students (see **Figures 2 and 3**) was taken into consideration when considering responses to the post survey (a baseline to determine any improvements).

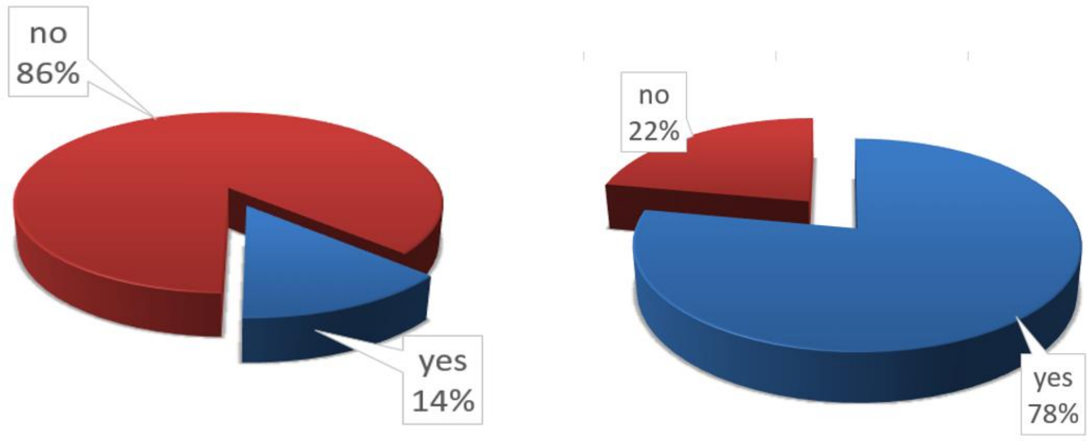

Figure 2: Students who have taken an ethics course at WPI or another learning Institution(left), and students who have encountered ethical concepts in their other classes (right)

Students were given nine statements about ethical knowledge and competence and asked how much they agreed with the statements. The total number of responses to the nine questions, and the percentage of students who answered in a particular way, are shown in **Figure 4**. 74.1% of students either agreed or strongly agreed with the 9 statements, while only 5.1% of students either disagreed or strongly disagreed.

Those statements were:

1. I can analyze a long-term problem to find an ethical solution.
2. I can represent my work ethically to management.
3. I can make suggestions to management for resolving an ethical problem.
4. I can write a proposal to resolve an ethical problem.
5. I can remain calm when facing ethical difficulties.
6. I know how to deal with unforeseen ethical dilemmas.
7. If someone opposes me, I can find ethical means to get what I want.
8. I can usually handle whatever ethical situation I find myself in.
9. It is easy for me to stick to my aims and accomplish my goals while maintaining ethical standards.

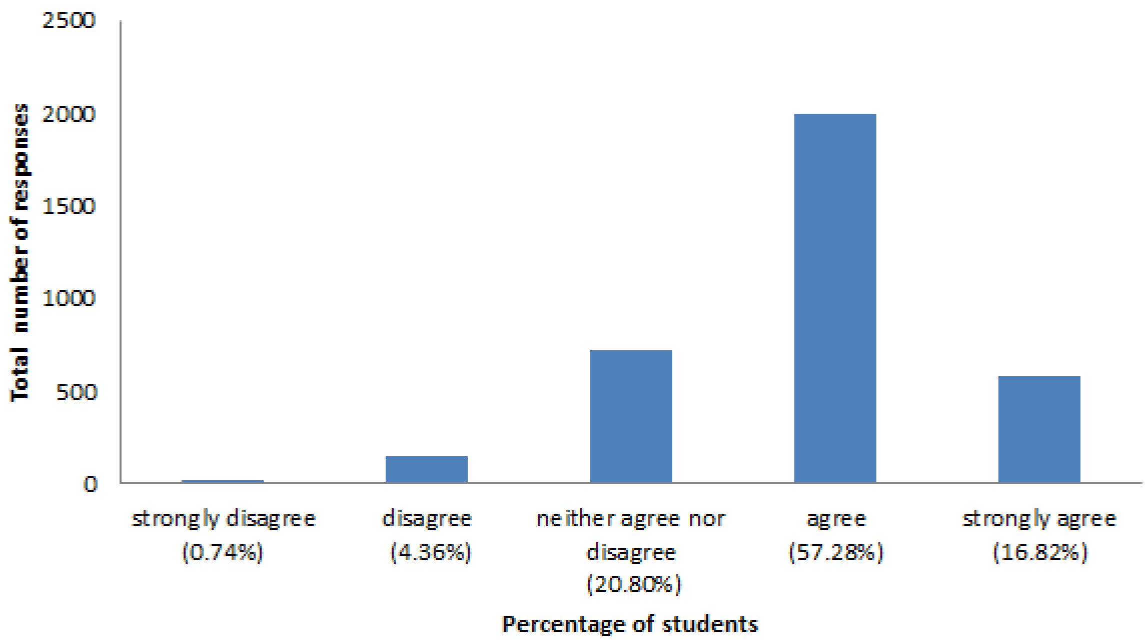

Figure 3: Total number or responses, and average number of students who chose each response to the nine statements

Post Ethics Module Survey:

After the students had participated in the ethics module, and completed the assigned case study, they were surveyed again to determine their feeling towards their improvement, and the module itself. They were separated based on the method, either joint-venture or blended, and the responses to each question for each method can be found in **Table 2** at the end of the section. The p-values for the questions between the two methods can be found in **Table 1** below. The p-values were used to determine statistical probability of difference between the two groups. It does not however, prove that they are the same. Graphical representations of each methods responses for every question can be found at the end of the section in **Figures 4 and 5**

Question	P-Value	Statistically different? (95%)
1. Was the material helpful with the assigned case?	0.013	yes
2. Are you more confident in answering ethical dilemmas than previously?	0.000	yes
3. Did you learn anything new regarding ethical situations?	0.000	yes
4. If encountered with an ethical situation in the workplace, could you identify analyse and handle it?	0.528	no
5. Would you be willing to take a 1/3 credit (full course) in ethics related to your major?	0.142	no
6. Would you like other courses in your major to incorporate similar ethical modules in the future?	0.000	yes

Table 1: P values for every question, and whether or not it could be shown that the two groups were different.

Out of the six questions asked, two could not be proven to be statistically different between the two methods, implying equality or a comparable result. The answers for the four questions that were shown to be statistically different were all in the favor of the blended method (see **Table 2** at the end of the section for responses) when it comes to learning or the desire for further learning. When looking at learning and competence, the blended method outperformed the joint-venture students in three of the four questions. More students from the blended approach found the material helpful when they were navigating the case study that was assigned to their class than did the joint-venture students (10% more students by class percentage) and they also had a higher amount of students report increased confidence (19% more), and learning new material (16% more). However, with regard to workplace confidence and competence, there was no statistical difference in responses between the two methods (92% and 93%).

When looking at an interest in future learning, only 56% of joint venture students and 64% of blended students reported a willingness to take a full course in ethics even though ethical knowledge is a requirement for degree outcomes. However, for both methods, more students wanted other courses to incorporate modules similar to the ones that they experienced (68% joint-venture and 85% blended).

Online				Joint-venture		
Yes	No	Total	Question	Yes	No	Total
157	23	180	1. Was the material helpful with the assigned case?	131	39	170
142	38	180	2. Are you more confident in answering ethical dilemmas than previously?	102	67	169
161	20	181	3. Did you learn anything new regarding ethical situations?	124	45	169
166	12	178	4. If encountered with an ethical situation in the workplace, could you identify analyse and handle it?	155	14	169
115	65	180	5. Would you be willing to take a 1/3 credit (full course) in ethics related to your major?	92	72	164
154	27	181	6. Would you like other courses in your major to incorporate similar ethical modules in the future?	111	53	164

Table 2: Responses to the post survey questions for blended (left) and joint-venture (right)

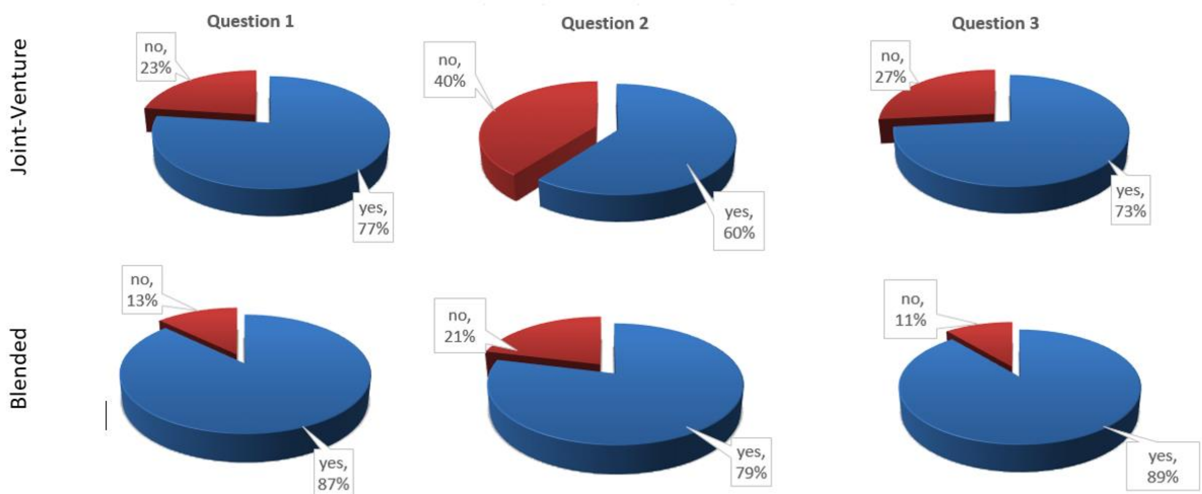

*Figure 4: student responses to questions 1-3 (found in **table** 2) separated by joint-venture (top) and online (bottom).*

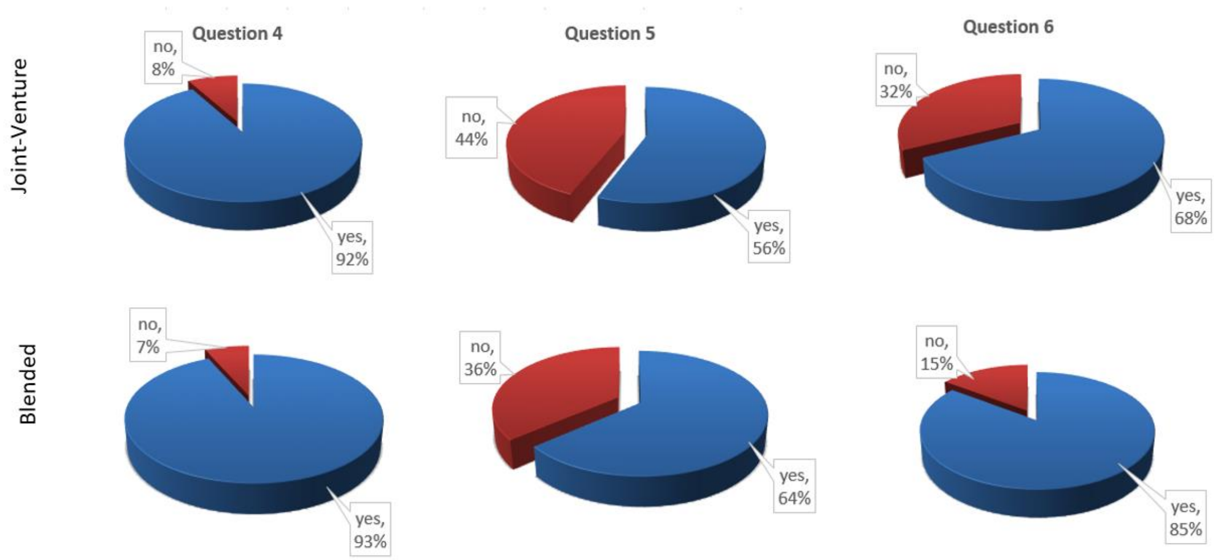

Figure 5 : student responses to questions 4-6 (found in table 2) separated by joint-venture (top) and online (bottom).

V. **Discussion**

Based on the data gathered on each method for this year's IQP, the blended approach proved to be as effective as the joint-venture approach. This study met the goal of our IQP in terms of creating a sustainable, more consistent, and scalable model that can teach students ethics in engineering as effectively as the joint-venture method utilized last year. About 92% of joint-venture students reported that they could identify, analyze, and handle an ethical situation in the workplace following experimental implementation, with approximately 93% of students in the blended method stating the same, a less than 2% difference. The determined p-value for the survey question was 0.528, indicating that the two responses were not statistically different. This supports the tested hypothesis that the blended approach could be as educationally effective as the joint-venture method.

Sustainability was one of the major considerations taken into account when choosing an approach for the problem. The main issue our team identified with last year's joint-venture approach was its consistency and repeatability. Both the joint-venture and the blended methods help students learn ethics, but the blended approach does not require a philosophy professor to teach the full ethics lecture for each individual class. Instead, after the initial work on the series was done, the videos could be used multiple times by any number of classes. These videos, as well as the class discussion being led by the regular professor of the engineering course, make it easier to coordinate with less people involved (Bird and Sieber, 2005). Additionally, the blended approach is easier for the engineering professors because many of them do not have the proper training to teach ethics (Frey and Cruz, 2003). These videos can be viewed during the students' free time and do not require a professor to sacrifice an entire lecture period for a joint-venture guest lecture. As a result, the blended module takes up less time in the classroom, which is beneficial because there is a lot of material to cover in the engineering courses already (Frey and Cruz, 2003). These factors make implementation of the model more appealing to professors, which will be useful if continued implementation is desired by future IQP teams.

The blended module is also a consistent approach because it does not require philosophy professors to come in and teach a lecture. There might be a year where a guest lecturer goes on sabbatical or works on an IQP. There could also be turnover in the philosophy staff where the regular lecturer might not be teaching anymore. New philosophy professors might not be interested in doing guest lectures.

Out of the six questions asked on the post-survey, two could not be proven to be statistically different between the two methods and four questions were shown to be statistically different in favor of the blended method. These results and their p-value analysis (found in **Table 2**) reinforce the hypothesis that the blended approach could be an equally effective method for education engineering students about ethics. The students found the blended method to be helpful and educational, and many who participated in this approach (85%) indicated that they would like other courses in their major to implement a similar approach. This indicates that there is a lot of room for this project to grow and that future implementation will likely find students ready and willing to participate.

Debbie Chachra (2005) outlines the means of effective online ethics instruction. She points out that while background information on ethics can be effectively taught online, the apparent lack of discussion hinders a purely online strategy's educational value. She establishes that discussing and evaluating differing viewpoints is integral in helping students learn about the nuances of ethical decision making. Our use of the blended approach addressed this problem by having in-class discussion sessions devoted to a selected case study. In addition, the videos displayed online had three professors participating in their own discussions on ethical theories and applied ethics. The discussion between the professors was intended to illustrate that ethics is not a concrete "right or wrong" topic even when being discussed by highly educated individuals on the matter. Chachra also states that good online instruction requires ethical study of situations relative to the student's field. This limitation in regular online study was also addressed by having an in-class discussion using the aforementioned case studies. Half of a class's regular lecture time was devoted to case study discussions for the blended approach group. Students were encouraged to express their opinions based on discussions facilitated by their engineering professors.

Another aspect Chachra outlines is that students should be taught to recognize ethical issues in their own technical work in classes. This is one detail that we could not directly test for as we have no insight on how much students have used what they learned from these modules in their daily academic lives. The team recommends that a future study implements this method in lab and design classes that involve more active decision making, thus making an environment that can be analyzed on whether or not a student takes ethics into account.

VI. <u>Future Recommendations</u>

Although the blended method was found to be as effective in the joint-venture model in teaching students about ethics in their engineering disciplines, there are still many improvements that can be made to make the blended method a more effective and scalable model. Regarding the online videos themselves, an increase in production value could drastically improve how the videos are received by students. In the context of this IQP, students found the videos to be monotonous at times and rather boring. With better direction and editing, the students could have an increased interest in the subject matter which could stimulate further study. In addition, the videos could also contain additional resources present for the students to look at, allowing for students to explore the material at their own pace.

From an implementation point of view, one goal for future projects would be to have online videos incorporated in all of the different engineering majors offered at WPI in an effort to prepare as many students as possible for the ethical decisions they will have to make in the workplace. By doing this, a larger population of engineering students would be subject to education about ethics, and a more systematic integration of the module could be tested. The hope of this IQP team is that this study shows that a blended approach can be used throughout all engineering curricula and that students get exposure to ethics for their full time at WPI. This would not only supplement a full course's worth of material, but also make the impression that ethics should be a constant aspect of an engineer's work.

The team also suggests an improvement on the type of measurement for each method's educational effectiveness. Both this project and last year's used surveys filled out by students as the main source of data to gauge educational value. However the survey responses only act as perceived increases or decreases in a student’s confidence or knowledge. One possible improvement on this is to implement a small quiz each student must complete that tests their information retention and ability to navigate ethical situations. By using data from these quizzes the results would be purely based on a student's ability and not what they think their ability is, thus giving more accurate results on the model’s educational benefit.

VII. <u>Conclusion</u>

Engineering students at WPI are not required to take an ethics course even though they must learn ethics in order to handle situations that will arise when they are in the professional world. This IQP has been dealing with this problem for the last three years. The goal of this year's IQP is to incorporate an alternative approach to teaching ethics that would be as effective as last year's joint-venture method, but would have the added benefit of being sustainable. We came up with a blended method to teaching engineering students ethics, where students learn the ethics material from online videos and then discuss a case study with the regular instructor of their engineering course. The joint-venture method was used in four engineering classes as a control to compare it to the blended approach that was implemented in two engineering classes. Data collected on both methods showed that the blended approach was as effective in teaching students ethics as the joint-venture method was.

Citations

Abraham, Nithin Susan, Abulencia, James Patrick. (April 1, 2011). Use of the LITEE Lorn Manufacturing Case Study in a Senior Chemical Engineering Unit Operations Laboratory. *Journal of STEM Education*. 12: 9-16. http://eric.ed.gov/?id=EJ940741

Billard, Kahn, Łichocki. (March, 2011). The Ethical Landscape of Robotics. IEEE. 39-50. doi: 10.1109/MRA.2011.940275

Bird, S. J., & Sieber, J. E. (2005). Teaching ethics in science and engineering: Effective online education. *Science and Engineering Ethics*, *11*(3), 323-328.

Cantwell, M., Lam, P., Reyer, K., & Rafferty, R.M. (2014) *Improving Ethics Education in Engineering* (undergraduate interactive qualifying project No. E-project-050514-202121). Retrieved from Worcester Polytechnic Institute Electronic Projects Collection: https://www.wpi.edu/Pubs/E-project/Available/E-project-050514-202121/

Chachra, D. (2005). Beyond course-based engineering ethics instruction.*Science and Engineering Ethics*, *11*(3), 459-461.

Colby, Anne, Sullivan, William M. (July, 2008). Ethics Teaching in Undergraduate Engineering Education. *Journal of Engineering Education*. 327-337. doi: 10.1002/j.2168-9830.2008.tb00982.x

Cruz, José A. Frey, William J. (December 2003). An Effective Strategy for Integrating Ethics Across the Curriculum in Engineering: An ABET 2000 Challenge. *Science and Engineering Ethics*. 9, 543-568. doi: 10.1007/s11948-003-0049-2.

Fan, W., & Yan, Z. (2010). Factors affecting response rates of the web survey: A systematic review. *Computers in Human Behavior*, 26, 132-39. doi: 10.1016/j.chb.2009.10.015

Graber, G. C., & Pionke, C. D. (2006). A team-taught interdisciplinary approach to engineering ethics. *Science and Engineering Ethics*, *12*(2), 313-320.

Healy, Tim. Teaching Ethics and Teaching Engineering–Some Parallels. *Santa Clara University.org*. http://www.scu.edu/ethics/publications/submitted/healy/teachethics.html Accessed on 10/10/15

Heerwegh, D., Vanhove, T., Matthijs, K., & Loosveldt, G. (2005). The effect of personalization on response rates and data quality in web surveys. *International Journal of Social Research Methodology: Theory and Practice*, 18, 85–99.

Jackson, X., Jasensky, Z., Liang, V., Moore, M. & Rogers, J. (2015) *A Joint-Venture Approach*

Teaching Students in How to Recognize and Analyze Ethics (undergraduate interactive qualifying project No. E-project-031515-151103). Retrieved from Worcester Polytechnic Institute Electronic Projects Collection: http://www.wpi.edu/Pubs/E-project/Available/E-project-050307-071942

Koskey, K., Cain, B., Sondergeld, T., Alvin, H., & Slager, E. (2015). A Mixed-Methods Investigation of Factors and Scenarios Influencing College Students' Decision to Complete Surveys at Five Mid-Western Universities. *Mid-Western Educational Researcher, 27*(1), 3-30.

Kumagai, Jean. (April 1, 2004). The Whistle-blower's Dilemma. *IEEE Spectrum*. http://spectrum.ieee.org/at-work/tech-careers/the-whistleblowers-dilemma. Accessed on 10/5/15.

Li, J., & Fu, S. (2012;2010;). A systematic approach to engineering ethics education.*Science and Engineering Ethics,18*(2), 339-349. doi:10.1007/s11948-010-9249-8

Newberry, B. (2004). The dilemma of ethics in engineering education.*Science and Engineering Ethics*, *10*(2), 343-351.

NSSE - National Survey of Student Engagement. (n.d.). Retrieved September 25, 2015.
Online Ethics Center For Engineering and Science. http://www.onlineethics.org/ Accessed on 10/11/15

Panitz, Beth. (October, 1995). Ethics Instruction: An Undergraduate Essential. *ASEE Prism*. 5, 2: 20-25. http://www.jstor.org/stable/24154353 Accessed on 10/11/15

Patel, Parachi. (September 25, 2015). Engineers, Ethics, and the VW Scandal. *IEEE Spectrum*. http://spectrum.ieee.org/cars-that-think/at-work/education/vw-scandal-shocking-but-not surprising-ethicists-say/ Accessed on 10/5/15.

Rabins, Michael J. (September 2012). Teaching Engineering Ethics to Undergraduates: Why? What? How? *Science and Engineering Ethics*, 4, 291-302. doi: 10.1007/s11948-998-0021-2.

Roberts, T. G., & Dyer, J. E. (2005). The relationship of self-efficacy, motivation, and critical thinking disposition to achievement and attitudes when an illustrated web lecture is used in an online learning environment. *Journal of Agricultural Education, 46*(2), 12-23.

Van de Poel, Suga-Fries. (2015). Teaching Ethics to Engineering Students. *Annals of Philosophy*. 63, 1: 213-216. http://www.jstor.org/stable/43410429_Accessed on 10/10/15

Wang, Wenping.(November 22, 2011). On the Status and Significance of Education on Engineering Ethics in Engineering Education. *Engineering Education and Management*. 111: 441-446) doi: 10.1007/978-3-642-24823-8_69

Wieling, M. B., & Hofman, W. H. A. (2010). The impact of online video lecture recordings and automated feedback on student performance. *Computers & Education*, *54*(4), 992-998.

Zandvoort, H., Van Hasselt, G. J., & Bonnet, J. A. B. A. F. (2008). A joint venture model for teaching required courses in ‘ethics and engineering’ to engineering students. *European Journal of Engineering Education*, *33*(2), 187-195.

Appendix A - Online Ethics Surveys

Pre-Survey

1. Have you taken an ethics course at WPI or at another institution?
2. Have you encountered ethics based content in any of your other courses?
3. How do you feel about the following statements?

    I can analyze a long term/recurring problem to find an ethical solution.

    I can represent my work ethically to whom I report to.

    I can make suggestions to peers for resolving an ethical problem.

    I can write a proposal to resolve an ethical problem.

    I can remain calm when facing ethical difficulties.

    I know how to deal with unforeseen ethical dilemmas.

    If someone opposes me, I can find ethical means to get what I want.

    I can usually handle whatever ethical situation I find myself in.

    It is easy for me to stick to my aims and accomplish my goals while maintaining ethical standards.

Post-Survey

1. Did you find the online lecture/discussion helpful in working with the assigned case study?
2. Did you learn anything new regarding how to analyze ethical situations?
3. If encountered with an ethical situation in the workplace, do you think you would know how to identify, analyze, and handle it?
4. Are you more confident in facing an ethical situation now than you were in the beginning of the term?
5. Did the ethics module distract from the technical core course work too much?
6. Would you want engineering courses to incorporate a similar ethics module in the future?
7. Would you consider taking a full (1/3 credit) engineering ethics course?
8. How did you feel about these aspects of the online discussion/podcast style video?

    -How enjoyable was the content? (1: hated it, 10: loved it)

    -How effective do you feel the content was in teaching the material? (1: not at all effective, 10: completely effective)

9. If the lecture material was not presented online, it could have been made available in class as a one day lecture and discussion. Knowing that, please answer the following questions

    -How would the in class lecture integrate with the engineering content, as compared to the online content?

    -Would you prefer a future ethics lecture in class as compared to online?

    How effective do you feel in class lectures are compared to online materials, based on your experiences in life?

10. If you could learn these concepts over again, how would you want to learn them?

-In class

-Online

-Combination of in class and online

-Other

Appendix B - Joint-Venture Ethics Surveys

Pre-Survey

1. Have you taken an ethics course at WPI or another learning institution?

2. Have you encountered ethics in any of your other courses?

3. How do you feel about the following statements?

-I can analyze a long term problem to find an ethical solution.

-I can make suggestions to management for resolving an ethical problem.

-I can remain calm when facing ethical difficulties.

-I can represent my work ethically to management.

-I can usually handle whatever ethical situation I find myself in.

-I can write a proposal to resolve an ethical problem.

-If someone opposes me, I can find ethical means to get what I want.

-I know how to deal with unforeseen ethical dilemmas.

-It is easy for me to stick to my aims and accomplish my goals while maintaining ethical standards.

Post Survey

1. Did you find the ethics guest lecturer helpful in learning the assigned case study?

2. Did you learn anything new regarding how to analyze ethical situations?

3. If encountered with an ethical situation in the workplace, do you think you would know how to identify, analyze, and handle it?

4. Are you more confident in facing an ethical situation now than you were in the beginning of the term?

5. Did the ethics module distract from the technical core course work too much?

6. Would you consider taking a full (1/3 credit) BME ethics course?

7. Would you want BME courses to incorporate a similar ethics module in the future?

8. If the lecture material was not presented in class, it could have been made available online. Knowing that, please answer the following questions

-How would an online program distract from the engineering content, as compared to the in class lecture?

-How would you prefer a future ethics lecture online, and compared to in class?

-How effective do you feel online lectures are compared to in class lectures/materials, based on your experiences in life?

9. How well did you understand/learn the material from the in class lecture?

-0-10

10. If you could learn these concepts over again, how would you want to learn them?

-In class

-Online

-Combination of in class and online

-Other

Appendix C: Case Studies Used for Each Class

BME 2210 Case Study

Pressure Monitor/Transducer Inaccuracy and Fluid Overload (adapted from Medical Device Safety Reports (MDSR) at www.mdsr.ecri.or)

A community hospital had traditionally used reusable quartz pressure transducers of the same brand as the physiologic monitors with which they were used. Wishing to cut reprocessing costs for the reusable transducers, the hospital began to evaluate disposable pressure transducers for use in clinical areas—namely, anesthesia, recovery, intensive care, and cardiac care.

The decision to evaluate disposable transducers was initiated by one of the hospital's departmental purchasing agents who gained physician approval and coordinated the purchase process on his own. He contacted a manufacturer of disposable transducers and met with one of its sales representatives, and arrangements were made for an in-service presentation by the transducer manufacturer. All nurses from the intensive care unit (ICU), cardiac care unit (CCU), anesthesia unit, and post-anesthesia care unit attended.

The sales representative presented an on-site program for day-shift nurses; evening- and night-shift nurses watched a manufacturer-produced videotape. These programs did not include an actual setup of a transducer to a patient monitor. The facility subsequently received shipment of the disposable transducers and began an in-house trial of the device.

One use during the in-house trial was on a 70-year-old female patient with a diagnosis of metastatic cancer of the breast, who was transferred to the hospital's CCU. Her attending physician inserted a Swan-Ganz catheter into the right pulmonary artery, as well as an arterial line catheter. The Swan-Ganz catheter was connected to a newly introduced disposable transducer. The arterial line catheter was connected to one of the old-style reusable quartz transducers. Both lines were connected to the blood pressure module housed within the physiologic monitor made by the manufacturer of the reusable quartz transducer. This was the first time that the CCU had ever used a disposable blood pressure transducer.

Upon insertion, the invasive pulmonary artery blood pressure readings from the Swan-Ganz line were very low. The digital numbers on the display monitor were low, and the graphically displayed waveform appeared “damped.” Pressure readings from the arterial pressure line were within normal physiologic range. Nurses re-zeroed the disposable transducer on the Swan-Ganz catheter three times, but the readings remained low. IV fluid therapy was immediately initiated.

The disposable transducers being used for the first time in other areas of the hospital were also exhibiting problems at this time, but not necessarily the same ones. Anesthesia personnel attempted to use one during surgery. They could not zero the transducer and switched back to the old-style reusable transducer. After this incident, the hospital contacted the disposable transducer representative, who corrected the problem by changing the cable. No hospital staff other than those present were made aware of the problem. The physiologic monitor used in surgery is of the same brand but is a newer model than those used in the CCU and ICU.

Coincident with this patient’s seemingly problematic pressure readings, the ICU contacted both the departmental purchasing agent responsible for the purchase of the disposable transducers and the hospital’s on-call biomedical technician about an inability to get an accurate waveform and digital readout from an arterial line connected to a new disposable transducer. The biomedical technician was unable to correct the problem. He substituted the disposable transducer with one of the newer model physiologic monitors that were being used in the surgical suite. This was the first time that the biomedical technician learned that the hospital was using disposable transducers. No further action was taken at the time.

The evening house supervisor (on the 3:00 p.m. to 11:00 p.m. shift) was aware of the ICU problem and informed the incoming night supervisor not to use disposable transducers for arterial lines. Nothing was said about using the disposable transducers for Swan-Ganz lines used for monitoring venous or pulmonary artery pressures. The disposable transducer used on the CCU patient was not changed. At about 36 hours after the low pulmonary artery pressures had been seen and fluid therapy started, the CCU patient’s Swan-Ganz catheter waveform became completely flat. A nurse who had previously heard about the ICU’s problem with the disposable transducer replaced the disposable transducer with a reusable Hewlett-Packard transducer. A good waveform was immediately obtained, and the Swan-Ganz readings were within normal range. No further action was taken.

The CCU patient died approximately three hours later. Postmortem examination determined that the cause of death was from massive fluid overload.

Investigation by the risk manager and clinical engineer revealed that the older model physiologic monitors have an internal blood pressure transducer sensitivity selector switch, which is accessible to engineering staff only through the top metal plate of the pressure module. The switch on the older-style CCU monitor was set for reusable transducers, not disposable transducers, thus yielding erroneously low Swan-Ganz readings. The clinical engineer knew of this feature of the older—but still clinically acceptable—monitors. Unfortunately, he had not been consulted during the purchasing process for the disposable transducers that were to be used with the capital equipment monitors. The newer monitors had a sensing circuit that would automatically adjust the monitor's transducer sensitivity setting.

Equipment evaluation and purchasing processes were changed at the facility to ensure that any disposable device that is connected to a piece of capital equipment was tested for compatibility. Further, hands-on, in-service training for use of such disposables was mandated.

Questions (answer on a separate sheet):

1. Identify the agents involved in the event and their moral responsibilities.

2. For one of the agents, identify their actions and their motives behind those actions.

3. Is the justification of using newer, less expensive disposable medical devices in this case study valid? Why or why not? Support your answer.

4. If you previously answered that using the disposable transducers was NOT justified, then write why it IS justified. Support your new response.
If you previously answered that using the disposable transducers was indeed justified, then write why it is NOT justified. Support your new response.

<u>ES 3002 and CHE 2012 Case Study (Provided by Professor DiBiasio)</u>

You are the lead engineer who has worked for Cleveland Chemical for five years and have enjoyed success and advancement as part of several design and manufacturing projects. You are the head of a process engineering team operating a new specialty chemicals process outside of San Diego, California. The plant is located south of Chula Vista in one of the poorest areas in the United States where both land and labor costs are low. One of your project engineers has brought it to your team's attention that the process uses a chemical that is not reported to the EPA under the Toxic Substances Control Act (TSCA). The TSCA requires listing, and subsequent EPA review of safety precautions and discharge controls, for all chemicals prior to use.

As the lead process engineer you have analyzed this chemical and know that there are special controls that keep the workers at the plant protected from the chemical's toxic effects. The chemical, however, after it is processed in the plant, gets discharged in a river that runs through Mexico. Currently Mexico does not require manufacturing companies to report chemicals that are being discharged into this river but has recently initiated an environmental policy where companies can voluntarily report a chemical that does. Mexican government officials will then be able to inform the residents who live in the villages around the river about the existence of this chemical and also will monitor the chemical's levels in the water supply. You know that if you report this chemical to the EPA, they will most likely cease production which will lead to major job losses at the plant.

a. What should you do as a lead engineer? Should you let Mexican officials know of this chemical even though the reporting is voluntary? How should you handle reporting it to the EPA?

b. Should this really be an ethical dilemma if your workers at the plant do not have any risks of exposure to this chemical?

c. Who are the stakeholders in this case (those impacted by this)?

d. If your own performance review is tied to the production schedule at the plant, how do you think your handling of this ethical dilemma will affect your review? Should it?

e. Take the counterpoint. If you chose to not report the chemical to the EPA or to Mexican officials, write why you actually should. On the other hand, if you chose to report it to the EPA and the Mexican officials write why you should not.

<u>ECE 2799 Case Study</u>

LOW-FREQUENCY ELECTROMAGNETIC FIELDS

By 1994, several studies had been performed that suggested a link between weak low-frequency magnetic fields and cancer or other health problems. The effects of these low-level fields, especially from electrical power distribution systems, first received widespread attention as the result of studies of childhood leukemia occurrences in residential areas of Denver, CO. These studies indicated that the incidence of leukemia was correlated to proximity of the child's home to transformers for residential electrical distribution. Although the correlation found in this study was small, it was "statistically significant."

Subsequently, there were many other studies both in the U.S. and Europe trying to verify these findings including studies of workers exposed to radiation from cathode ray tubes (such as computer monitors) and workers for electric utilities. The results of these studies were controversial, and not all research led to the same conclusion. In fact, as more refined and controlled studies were performed, the harmful effects of the fields seemed to diminish.

Laboratory studies were also initiated to determine the biological effects of low-frequency magnetic fields. These were typically performed on cell cultures or laboratory rodents. The results of these studies were conflicting and inconclusive, and since no studies had been performed on humans, the relationship of any results to human health was debatable.

These studies presented engineers with a problem: how to design safe products without fully understanding the nature of the dangers. A wide variety of common household items had been found to emit significant magnetic fields, including toasters, electric blankets, and even the clock radio sitting at many bedsides. Some products could be redesigned to reduce or eliminate this problem, but of course any design which will lead to reduced emission will probably cost more.

More recently, the evidence for health effects of these fields has been reviewed by panels of several professional societies. Both the IEEE and the American Physical Society have concluded that there is no evidence indicating that there are any harmful effects, although critics suggest that both of these organizations have vested interests in obtaining this finding. It seems that for now the concern over low-frequency electromagnetic radiation was unfounded.

1. A stakeholder is an individual, group, or organization that has interest in and can be affected by another's actions. Who are the stakeholders in this case?
2. Must the product be engineered to be totally safe at all costs? How can an engineer best balance safety with cost in this case?
3. In light of the findings of several professional organizations that indicate that there is no hazard associated with low-frequency magnetic fields, what should an engineer do today when designing products that will emit this type of radiation?

Source: T. S. Perry, "Today's view of magnetic fields," IEEE Spectrum, vol. 31, pp. 14–23, Dec. 1994.

RBE 3001 Case Study

There have been big strides made this millennium in the field of robotics. (39) Engineers have made robots for a variety of different purposes, whether it is to serve human beings or be used as weapons by the military. (39) The selling of robots for household tasks has drastically increased for the last decade, "and reached 7.2 million robots by the end of 2009." (39) A group of robotics engineers have been asked to design robots that will be used to help care and give companionship to the elderly. This could, overtime help with the costs of homecare as the robot may be initially an expensive investment for a homecare firm, but would be cost-saving over time. One member of the engineering team conducted research on the use of robots for the elderly and found that having a robot be a companion helped elderly patients who had dementia. (43) In doing research he found that there is possible evidence that shows that when an elderly person interacted with a robot, it "may improve the pattern of brain activity" (43). Another robotics engineer on the team found in her research that robots were helpful in reminding patients to take their medications. (43) However, one of the nursing home directors that the robotics team consulted with met with the team and expressed her concerns that having robots involved with the care of elderly patients takes away the human interaction that these patients need. (43) She noted that communication with humans makes these patients feel less isolated. (43) Further, it is unclear how the robot would exhibit compassion and care in the ways that a human companion can.

Questions:

1. Explain the ethical dilemma that the robotics engineering team is faced with.

2. Do you think the robotics team should make these robots for the elderly? Why or why not?

3. Take the counterpoint. If you decided to make the robots, why should you choose not to make them? If you chose to not make the robots, argue why the robotics team should make them.

Source: "The Ethical Landscape of Robotics" *IEEE Xplore Digital Library* 4/14/2011 Accessed: Thursday, January 21, 2016
http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=5751972&tag=1

ES 2502 Case Study

Ethical Issues in the Design of Ultra-Lightweight Vehicles

A multidisciplinary design team consisting of undergraduate and graduate students from Aerospace Engineering, Applied Earth Sciences, Industrial Design and Mechanical Engineering at the Delft University of Technology in the Netherlands is designing a lightweight, sustainable car. Their goal is to design a family car with a maximum mass of 400 kg. Mass is an important factor in the fuel consumption of a car, a light car can be very energy efficient. The target mass is less than half of that of normal cars. (European family cars usually weigh about 1200 kg and the average American car weighs 1360 kg). Another requirement is that the car should be manufactured at affordable mass production costs.

The goal of reducing the mass to 400kg has generated a debate over safety concerns when building a lightweight car. A car that is relatively light always has a disadvantage in collisions with larger cars in that it will always experience the greater acceleration. Traditional automobile safety considerations have resulted in designs of very heavy and stiff vehicles, protecting the driver and passengers in a collision but at the same time constituting a hazard for other road users in lighter vehicles because of their significantly reduced stiffness and mass. In addition, heavier vehicles are not as fuel efficient. Recent developments in automobile safety have led to the increasing use of passive safety systems such as airbags and active systems like Anti-lock Braking System and night vision enhancements. Designing in the conventional way means that safety systems are included as much as economically feasible. In a car of 400 kg or less it is very difficult to include extensive active and passive safety systems, so the design of a lightweight car necessitates a reconsideration of the ideas of what constitutes adequate car safety. Is it a car that performs well in crash tests, or is it a car that helps the driver to brake suddenly to avoid a crash? There is a theory within safety science that states that people have a target risk that guides their behavior, and this is called risk homeostasis. People will try to keep the perceived risk at the same level. A driver that feels safe and protected by her car will speed more. This could lead to accidents with higher speeds involved and therefore more injuries and damage. The same driver would probably not speed in a subcompact, as she will probably feel more vulnerable. Therefore, there might be good arguments to build a car with less active and passive safety systems. The Delft student designers have chosen to design a car with few systems, good handling, but one that makes the driver feel a bit vulnerable. This choice is inspired by the lightweight criterion and the risk homeostasis theory.

These are the questions that correspond to the safety portion of the ethics case study.

1. In designing a lightweight car that is arguably not as safe as a normal vehicle, does a safety engineer risk violating their professional code of ethics?

2. Risk and cost benefit analysis are critical components of any engineering process. Describe the ethical issues that a designer of a lightweight car faces when conducting these analyses.
3. If the theory of risk homeostasis is correct (there are debates about this, some studies indicate that the theory is empirically verified and others claim that the theory is empirically refuted), is it ethical to design cars for perceived levels of risk? Why or why not?
4. What are some of the arguments against your answer to Question 3? Try to view the issue from the opposing point of view.

Source: Ethical Issues in the Design of Ultra-Lightweight Vehicles" Online Ethics Center for Engineering 2/27/2006 National Academy of Engineering Accessed: Sunday, November 29, 2015 <onlineethics.org/Resources/Cases/ULV.aspx> from http://www.onlineethics.org/cms/5089.aspx