Sustaining Ethics Education in Engineering: A Blended Approach to Ethics Instruction

Zack McKinzie, Wasih Kamran, John Hobson, Dylan Renshaw, Kristen Billiar, and Geoffrey Pfeifer
Worcester Polytechnic Institute

Corresponding Author: Geoffrey Pfeifer, gpfeifer@wpi.edu

Introduction

Engineers must understand that ethical responsibility is important for their careers. Engineers encounter different ethical dilemmas on a daily basis that may require careful thought to overcome. However, many do not have the ability to recognize and navigate through ambiguous ethical situations because of a lack of training (Bird and Sieber, 2005). Therefore, it is important that engineering students learn ethics while they are in college to deal with problems that arise in the workplace.

A 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. A course completely dedicated to ethics instruction can educate students in more detail than integrated classes discussed below. (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).

Another method that can be used to teach ethics to engineering students is incorporating ethics into engineering classes across the curriculum. The instructors teach the regular engineering material in class as well as professional ethics. By teaching ethics on a daily basis, the students will learn how ethics is an essential component to an engineer's career.

Teaching ethics in many classes also connects ethics to the engineering topics in class (Li and Fu, 2012). One of the problems to this approach is that it essentially requires all engineering instructors to know how to properly teach ethics to students. This is problematic because some engineering faculty lack ethical awareness themselves. 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).

To combat some of the drawbacks of teaching ethics via a standalone course or by inclusion across the engineering curriculum, a joint-venture model can be used. This method involves a professor from the philosophy department who is well-versed in the theory of ethics providing a guest lecture for an engineering course. This provides students with a broader ethical background and allows professors to build from basic ethical theories to actual application of ethics. In addition, the normal engineering professors are able to link ethics to the students' technical coursework (Graber and Pionke, 2006). This method emphasizes the consistent inclusion of ethics in the student's coursework, eliminating the issue of having ethics perceived as a separate entity in an engineer's work (Li and Fu, 2012).

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 regularly volunteer their time are still not guaranteed to teach such lectures every year, seeing as they might be on sabbatical that term and cannot participate. Furthermore, the technical classes they 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 poses a challenge to administering all of the technical aspects required of the course.

This study proposes a blended approach that uses online lectures to teach ethics, which provide an avenue to overcome some of the issues with the aforementioned joint-venture model. Online lectures provide a large degree of flexibility both from the end of the instructor as well as the student (Bird and Sieber, 2005). Philosophy instructors are able to record and develop these modules on their own time and technical professors can implement them as they see fit without interfering with their rigid lecture schedules.

Online lectures have been found to be effective supplements of in person lectures in teaching core theories and laws (Wieling and Hoffman, 2010). One major flaw with exclusively lecturing online is the lack of in-class discussion; students will discuss ethical topics, pose different arguments, and come up with ways to handle ethical dilemmas in a classroom environment. An approach that only teaches through online education will not give students that critical aspect of ethics education (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.

A previous project at Worcester Polytechnic Institute (WPI) detailed a joint-venture approach that proved to be effective in educating students on engineering ethics. Although the students' perceived confidence in handling ethical situations increased, the study was limited to three classes and only a joint-venture model with one guest lecture in each class was used. We sought out to formulate a method that could be as effective in teaching students ethical content, but also address the issues with the joint-venture model; mainly sustainability and scalability.

In this work, we proposed a blended online method to take advantage of delivering ethical theory via online videos and also has students engage in in-class discussions revolving around a case study pertinent to the class, with the engineering professor leading the discussion. The online videos in theory solve the problem of year-to-year educational consistency by having philosophy professors sit down and record videos at one given time. Those videos could be used in multiple years for multiple classes. Additionally, the in-class discussions address the problem of sustainability with a purely online method of education. The discussions allow students to hear differing viewpoints and hear the experiences of their own engineering professors. We hypothesize that the blended approach will be as effective in teaching students engineering ethics as the previously mentioned joint-venture model.

Methodology

The aim of this project was to assess the viability and sustainability of a blended 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

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 spoke. 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. 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 Electrical and Computer Engineering Design). The exact amount of credit was determined by the regular professor of the class. The classes used for this group were 1) Biomedical Signals, Instruments and Measurements, 2) Electrical and Computer Engineering Design, 3) Mass Transfer, and 4) Unified Robotics I. The classes contained 117, 23, 65, and 37 students respectively, and were mostly comprised of sophomores.

The blended approach required the group to recruit several philosophy professors who were willing to be filmed while they discussed the ethical topics that were outlined by the group. Using the footage, three separate online videos were made 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 institution's 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 online 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 online. 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 Stress Analysis and Elementary Chemical Processes. These classes were comprised of sophomores and juniors and contained 96 and 112 students respectively.

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 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, $p<0.05$.

Analysis

The number of students for both the joint-venture and blended approaches was approximately the same (around 170 each). 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 **Figures 1 and 2**) 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.

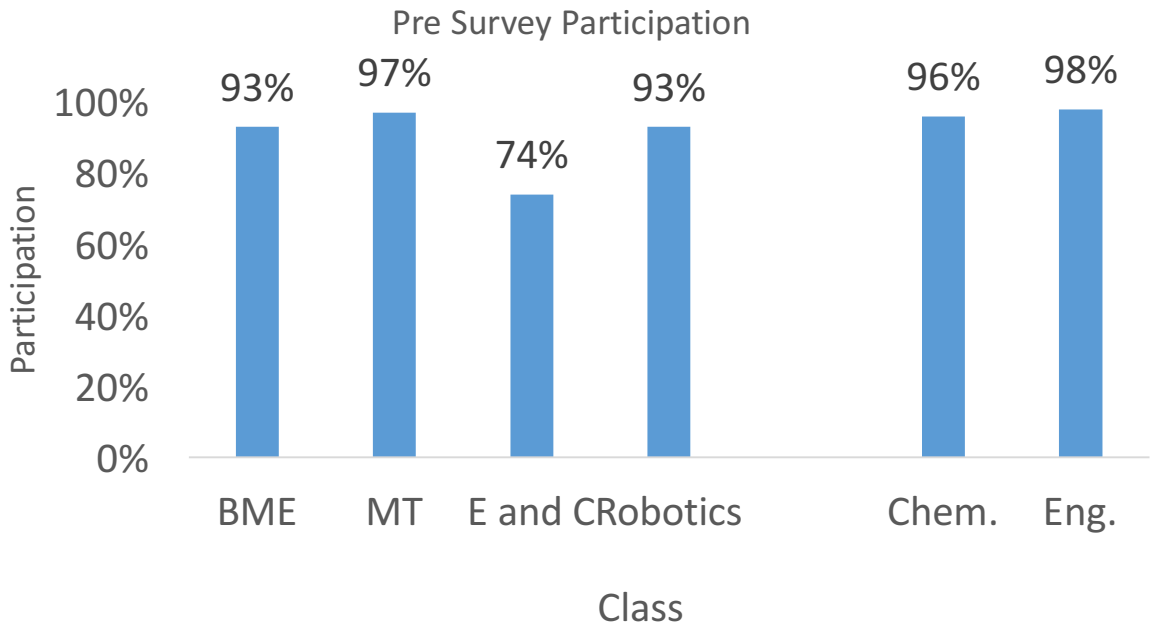

Figure 1: *Participation by class for Pre-module survey. Class names from left to right: Biomedical Engineering, Mass Transfer , Electrical and Computer Enginnering design, Unified Robotics, Chemical Engineering, and Stress Analysis.*

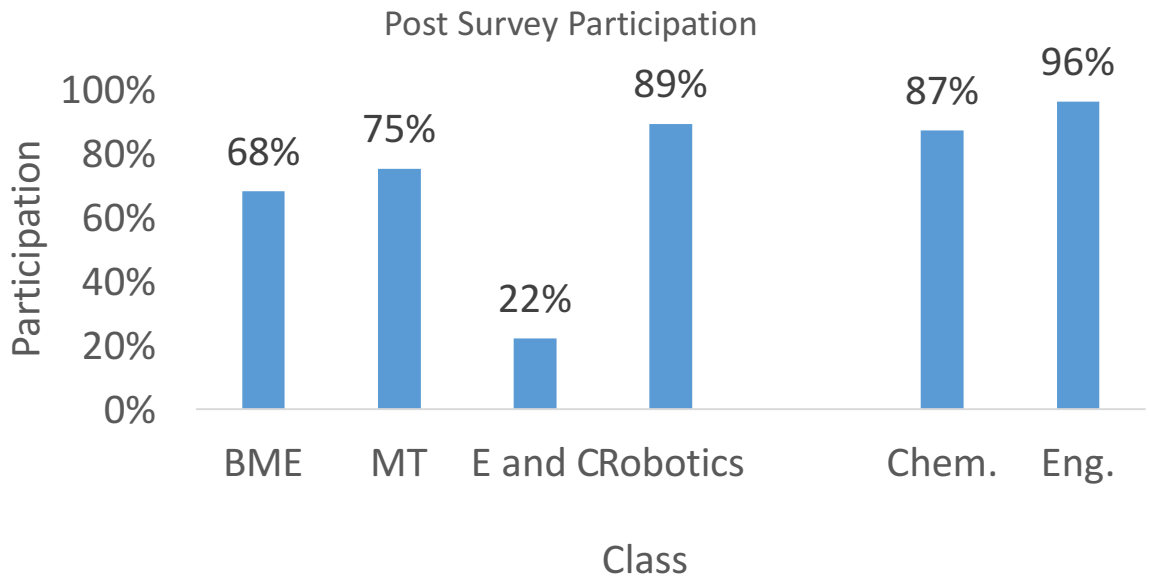

Figure 2: *Participation by class for the post-module survey. Class names from left to right: Biomedical Engineering, Mass Transfer , Electrical and Computer Enginnering Design, Unified Robotics, Chemical Engineering, and Stress Analysis.*

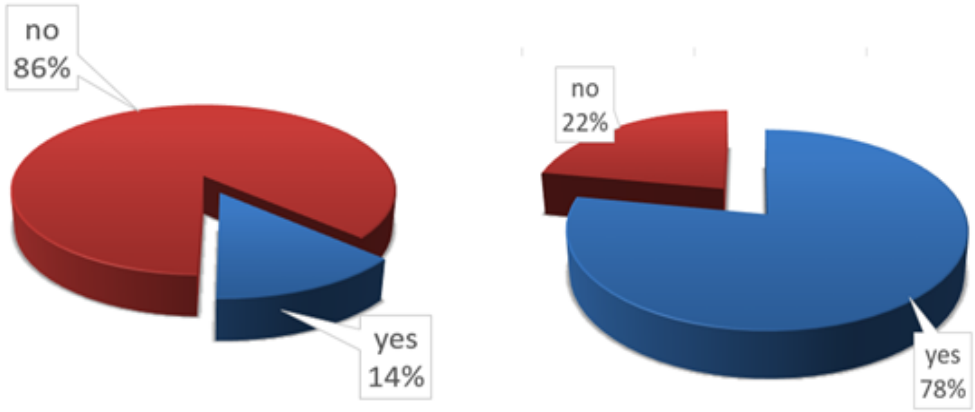

Figure 3: *Prior Exposure to ethical concepts.. (Left) Students who have taken a course in ethics at WPI or another institution. (Right) Students who have encountered ethics in their other courses.*

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

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**. Based on the data 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 and the students' responses 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.

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 1.

Table 1: *Student responses by module method to the post survey. (Left) Students who were assigned the online method. (Middle) The question the students were responding to. (Right) students assigned to the blended method.*

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

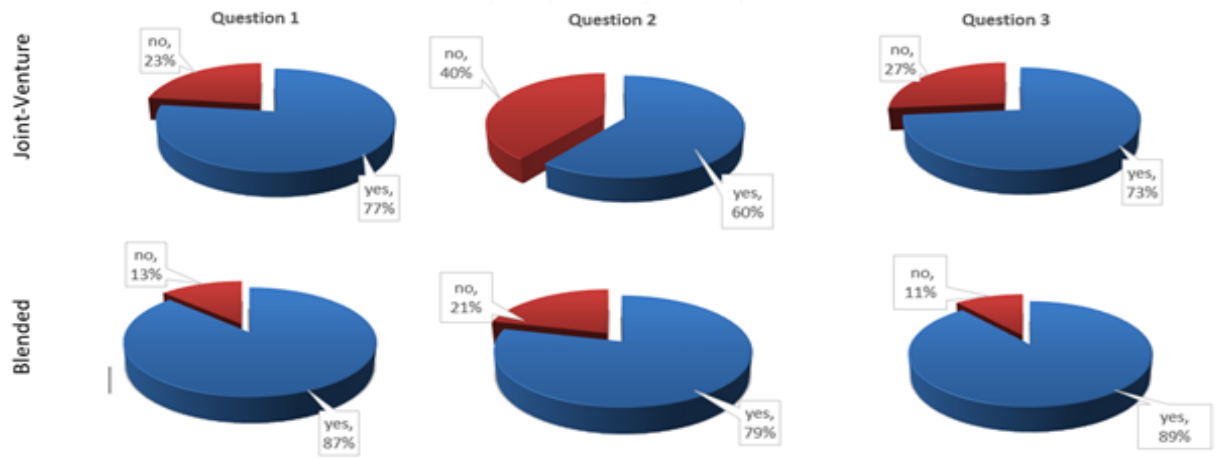

Figure 4: *Graphs for Table 1 questions 4-6 (left to right). (Top) Joint-venture approach. (Bottom) Blended approach.*

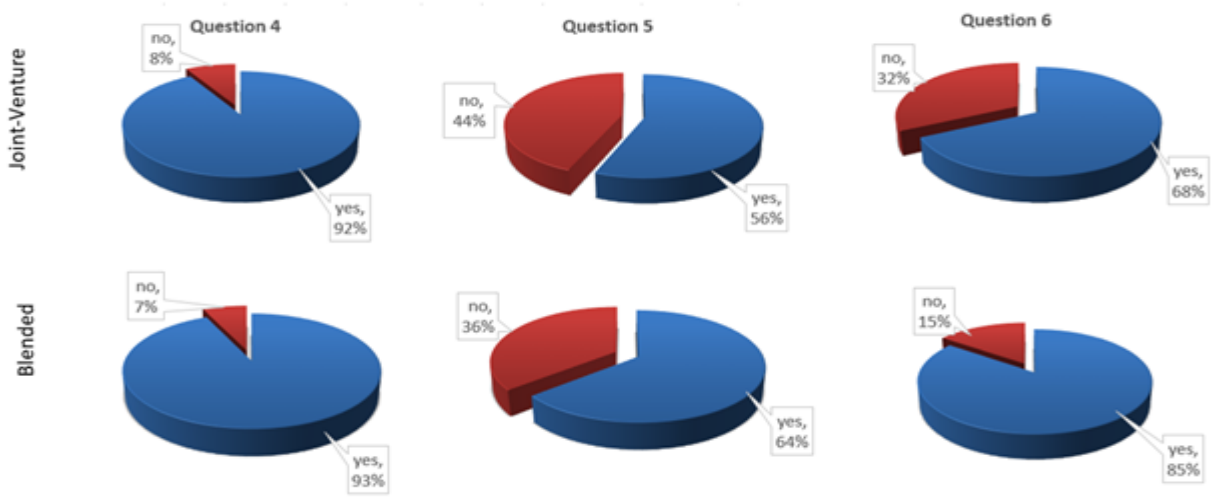

Figure 5: *Graphs for Table 1 questions 1-3 (left to right). (Top) Joint-venture approach. (Bottom) Blended approach.*

Graphical representations of each methods responses for every question can be found in **Figures 5 and 6**.

The four questions that had statistically different results between the methods were all in the favor of the blended method (see **Table 2** at the end of this section for P values) 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 regards 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). These results show how both methods helped stimulate students' interest in ethics.

Table 2. *P values for the post survey questions.*

Question	P-Value	Significant
1	0.013	yes
2	0.000	yes
3	0.000	yes
4	0.528	no
5	0.142	no
6	0.000	yes

Based on student feedback, the blended approach proved to be as effective as the joint-venture approach. This study met our goal 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. The statistical analysis comparing each method's survey data concluded that the methods were either not statistically different or that the blended method outperformed 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 the 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 for continued implementation of the approach.

The blended module is also a consistent approach because it does not require philosophy professors to come in and teach a lecture for each course. There might be a year where a guest lecturer goes on sabbatical or works on a project off-campus. 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.

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.

Another aspect Chachra highlights is that students should be taught to recognize ethical issues in their own technical work in classes. 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.

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. 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 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 is to have online videos incorporated in all of the different engineering majors 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 will be subject to education about ethics, and a more systematic integration of the module could be tested.

Improvement on the type of measurement for each method's educational effectiveness will also be of benefit. This project 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 approach 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 will 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.

Conclusions

The goal of this project was to find a more sustainable and scalable mode of ethics education that was as effective as a joint-venture model of teaching. The proposed blended method used online videos to teach ethical theory and in-class discussions to apply ethical theories in the context of engineering. The blended approach was tested alongside a joint-venture model and our findings indicated that the methods were equally effective at teaching students engineering ethics. However, student survey data was used as the only measurement of educational success, so only perceived educational benefit was measured. The group suggests that future implementation applies the blended approach across a larger scale and that a more accurate measure of information retention is used. Through a systematic integration of the blended approach with professional production of ethics videos, it is feasible that this method can be used to teach students ethics across the entirety of their engineering education.

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