May 2014

Improving Ethics Education in Engineering

Kevin Andrew Reyer  
*Worcester Polytechnic Institute*

Meghan Barbara Cantwell  
*Worcester Polytechnic Institute*

Peter Chap Lam  
*Worcester Polytechnic Institute*

Richard Matthew Rafferty  
*Worcester Polytechnic Institute*

Follow this and additional works at: [https://digitalcommons.wpi.edu/iqp-all](https://digitalcommons.wpi.edu/iqp-all)

**Repository Citation**

This Unrestricted is brought to you for free and open access by the Interactive Qualifying Projects at Digital WPI. It has been accepted for inclusion in Interactive Qualifying Projects (All Years) by an authorized administrator of Digital WPI. For more information, please contact [digitalwpi@wpi.edu](mailto:digitalwpi@wpi.edu).
Improving Ethics Education in Engineering

A Course Qualifying Project

Submitted to the Faculty of

WORCESTER POLYTECHNIC INSTITUTE

in partial fulfillment of the requirements for the

Project Title

By

Meghan Cantwell, Peter Lam, Kevin Reyer, Richard Matthew Rafferty

May 5, 2014

Approved by

Prof. Kristin Billiar, PhD

Biomedical Engineering Department
Contents
Introduction ............................................................................................................................................................................... 3
Background .............................................................................................................................................................................. 4
Methods and Materials ........................................................................................................................................................ 12
Results ...................................................................................................................................................................................... 18
Discussion ............................................................................................................................................................................... 23
Future Study ............................................................................................................................................................................. 28
Conclusion ............................................................................................................................................................................... 29
Works Cited ............................................................................................................................................................................. 30
Appendix ................................................................................................................................................................................ 33
Introduction

Ethical awareness of issues is important for engineers that make decisions that will impact society. All engineering decisions involve ethical considerations. Engineering is a vastly expanding field with many unique aspects that give rise to many ethical situations not addressed in formal technical calculations. Without understanding the ramifications of ethics in engineering, engineers may make decisions in the world that will have a negative impact on other people. Students must understand the importance of ethics to make decisions that limit harm to society. Society requires a high degree of ethical understanding, and all of the engineering industry must display the ability to act ethically. Although industry exposure in ethics is a valuable mode of education, universities provide a great environment for introducing ethics education and understanding.

It has been argued that ethics should be made central to the engineering curriculum and not peripheral to it (Moore, 2010). Better training is needed for engineers in terms of ethics understanding. Many universities have attempted to improve ethics education, but a majority of them were unsuccessful. Students lack interest in ethics education and tend to avoid taking ethics based courses (Herkert, 2006). Students are not receiving exposure to the types of ethical issues that they might face in their careers (Herkert, 2002). Professors often do not teach ethics at all or only include one or two lectures on the subject. The amount of time spent on teaching ethics in engineering based courses is insufficient to teach the required strategies and convey types of ethical issues that students need to understand. Currently, there is not a set standard for teaching ethics in engineering. The ABET accreditation board briefly mentions ethics in their accreditation criteria. However, the lack of emphasis on ethics by ABET allows programs to deemphasize ethics in their curriculum. One major issue is the lack of resources for ethics education in courses and professors’ ability to implement ethics analysis. From the ABET report on the biomedical engineering program of Worcester Polytechnic Institute, only three of the BME courses addressed the outcome for ethics understanding.

The focus of our project is to develop methods and materials to incorporate ethics education into the biomedical engineering curriculum at WPI. Our purpose is to provide easily implementable resources for improving ethics education that are engaging to both professors and students. As a result of the lack of resources for teaching ethics, we will attempt to create resources for engineering professors to teach ethics in their core engineering classes. Our approach is to conduct surveys on students, professors, and industry for their perspective on ethics education in engineering. The surveys will help us better understand the specific needs in the subject. We will then develop methods to teach ethics using our data along with performed research. Success will be measured by feedback from students on how engaging the methods were, and feedback from professors indicating the ease of implementation. If our methods for teaching ethics are successful, they can be used by professors across the nation to better educate their students. The created methods can help prepare engineering students to make ethical decisions throughout their careers and improve the welfare of society.
Background

Importance of Ethics in Society and Engineering Industry

Due to the impact of their work on society, engineers have an ethical responsibility for its safety and welfare. This responsibility requires understanding of the importance of ethics, and its application in engineering endeavors (Wulf, 2004). Ethics is first taught by parents and family members and is a crucial part in maturity. Within everyday life and career, ethics are deeply woven into the decision-making processes, making it a standard of life. These standards should be harvested and refined through higher education. In higher education, it is essential to emphasize engineers’ role in the safety of communities, making clear the role for applied ethics (ASEE, 2013). This role is defined by society's need of ethics (Wulf, 2004). Ethics is a system of moral principles defined by a group and utilized in guiding decision making to the morals and needs of the group (BBC, 2013). An ethical issue is a problem or situation that requires a person to choose between alternatives that must be evaluated as ethical (right) or unethical (wrong). Therefore, in society the goal is that high ethical standards will allow for improved decision-making on morally complex issues in ways that respect and benefit society and its constituents.

Current Situation of Ethics Comprehension

In his analysis of the state of engineering ethics, former National Academy of Engineering President, Wm. A. Wulf discusses the current structure and issues of the topic. Engineering is often guided using codes of engineering and general principles of practice to encourage ethical behavior. Also, Wulf notes the majority of engineers behave ethically, and that current issues are not due to moral decline of engineers in the field. However, these codes are focused on individuals and their behavior, not the field of engineering as a whole; clearly this cannot be the extent of ethics in engineering (Wulf, 2004). In using codes alone, engineering industries are not able to reach the needed ethical responsibility required by society. Combined with the expansion of engineering’s ability to shape society, the individual and internal focus of engineering ethics codes are insufficient to address society’s ethical needs. These issues are broader, on the scale of the entire profession of engineering, not just the ethics of individual engineers. Without the ability to work with these macro-scale ethical needs, engineering developments will create problems due to ignoring these needs at their individual working levels. For example, biomedical engineers may produce an improved medical device that is expensive resulting in a higher cost of healthcare. People who cannot afford the new device would have to continue using older devices that might not work as well. Therefore, knowledge only of codes of ethics is not sufficient. Redefinition of ethical engineering in society and the method of imparting this understanding to engineers is needed. The current state of engineering industry lacks the ethical understanding society requires (Wulf, 2004).

Inadequate Emphasis of Ethics in Education

The lack of understanding of ethics in the engineering industry, such as the Depuy Hip
Replacement Lawsuit, is due to weaknesses in engineering education (Lewis, 1988). This is a result of the lack of focus on ethics throughout the discipline, demonstrated by the fact that there are no standardized methods of achieving it. Newberry, a Professor at Baylor University, teaches ethical issues in engineering. He states that the promotion of ethical behavior is the highest value for teaching ethics in engineering disciplines. However, varying opinions as to what ethics means yields different interpretations of ethics in education. This statement leads to different preferred methods of delivery (Newberry, 2004). Three of the objectives in ethical education are to help students want to make ethical decisions, to have the ability to make these decisions, and most simply, to be aware of the relevant codes and guidelines guiding the appropriate ethical practice (Herkert, 2002).

Newberry notes that teaching ethics to engineering students is difficult because their technical work takes up so much of students’ time, focus, and loyalty (Newberry, 2004). Because engineering and technical courses are so demanding, the American Society of Civil Engineers (ASCE) has stated that a master’s degree is to be the first professional degree. For them, four years plainly is not enough time to take in the vast amount of technical knowledge and skills as well as the societal, political, and ethical implications of their engineering projects (Epstein, 2002). With this lack of standard methods or focus on ethics education, engineering students can enter the engineering industry without the necessary education that provides the ethical understanding society requires. This demonstrates that there is a problem in engineering education, and it needs to be addressed to solve the engineering industry’s failure of ethics understanding.

Current Education Structures and Practices

The cause of this problem in engineering education is due to the lack of current structures and practices for instilling ethics understanding. Tools to emphasize importance of ethics include the professional engineering code of ethics and engineering codes of standards institution accreditation requirements, and attempts at the ethics education in engineering.

Professional Ethics

Professional societies develop polices for their own industries, and the societies hold their members to that code of ethics. Professional ethics is different from studying philosophical ethics. Professional ethics encompass how people work in a professional setting by following expected standards of behavior (Strahlendorf). Professional ethics goes beyond simple right and wrong decisions; it delves into the actions a professional should take in the workplace. It is difficult to change the morals of a person, however it is possible to teach a person to think ethically in the professional field through education. Especially within the engineering industry, a person needs to think of how her actions will affect others, and how she can impact society in a beneficial way or at least prevent harm (Weil, 2008). It is important to point out this project will not look into covering professional ethics in the context of worker relationships or ethical dilemmas not related to engineering decisions. Although these issues are important, and it is
necessary to act ethically in any situation, many companies perform well in training their employees in the standards of their particular workplace. For this reason, only ethics of engineering will be examined in greater detail.

Codes of ethics have been created by many professional societies to set a standard of ethical conduct for professionals in their fields of study (Weil, 2008). The National Society of Professional Engineers produced a general code of ethics for all engineers, most recently updated in 2007 (Engineers, 2007). This code states six fundamental canons that engineers should fulfill in their duties. In summary, these canons state that an engineer should always have public safety in mind and report findings to public. They should only perform services in their area of expertise. They should be faithful and avoid deception while conducting themselves in an honorable, responsible, and ethical way to enhance the reputation of their profession. Engineers search for very descriptive codes of ethics because it makes it simpler for them to approach an ethical dilemma. However, it has been argued that codes of ethics are unnecessary from an ethical standpoint because they are too vague and unrealistic. The standards that current codes proclaim give reason to believe that there is value in the codes, and they do lead to ethical decisions. Furthermore, if these codes had been employed properly in past situations, they could have improved ethical decision making (Davis, 1991).

Although using codes of ethics may be an informative and effective framework, memorizing what the codes are and promising to follow them is not adequate preparation for what is to come in an engineer’s career. Codes should be used as a basis for instruction only if professors focus on and show the value of these codes by emphasizing to students how they relate to their future lives and work. Codes of ethics are valuable tools but, are not sufficient enough to outline a comprehensive conception of goals and provide ethics understanding. There is a further need for ethics education than what is given through codes of ethics.

Accreditation Requirements

The ABET accreditation board has pushed for the inclusion of ethics education in universities across the nation. In 1997, ABET adopted the Engineering Criteria 2000, and all engineering programs have been accredited using the new set of standards since 2001. In the new criteria, ethics has been added to encourage universities to implement ethics education into their engineering programs (Peters, 1998). Criterion 6 states engineering programs must indicate their students have the perception of ethical and professional responsibility. This criterion is closely related to criterion 8, which states graduates should have an understanding of the impact of engineering solutions in the context of society. Even though ethics is not mentioned explicitly in criterion 8, it is implied the students should have ethical knowledge of how engineering decisions will impact society. With the addition of ethics in the new set of ABET standards, engineering programs across the United States attempted to implement ethics education for their students (Herkert, 2006).

Current Obstacles of Ethics Education Implementation
With the criteria from ABET, implementing changes to the curriculum in engineering programs for ethics is a new challenge. A major issue with ABET’s requirement is its vagueness makes it difficult to implement a standard model for teaching engineering ethics (Herkert, 2002). A survey of ABET accredited institutions showed 70% of the surveyed institutions did not require their students to take an ethics-related course. The institutions that do have a requirement for an ethics-related courses often do not offer specialized courses in engineering ethics, but only offer ethics in the context of philosophy and religion (Herkert, 2006). Many departments simply include small ethics lectures in the curriculum to meet the ABET requirement. For this reason, many classes lack emphasis on ethics and lead to an undereducated student (Moore, 2010). The problem escalates when engineering faculty lack the commitment to implement ethics material into their courses. Engineering professors would rather focus on the technical aspects of engineering than ethics because that is their expertise (Peters, 1998). Students also lack the interest to learn ethics or realize its importance. A survey was done in Georgia Tech on engineering undergraduates on their opinion of the new ABET criteria, and this survey indicate that undergraduates feel emphasis on traditional engineering concepts is more important than concepts associated with an engineer's role in society, including the ethical responsibility of engineers. The students do not understand the importance of the ethics related criteria or the reasons why ABET included it. Students must realize that engineering ethics is important for entering the workforce. These problems must be addressed to implement engineering ethics into the curriculum effectively (Peters, 1998).

One study found that few engineering programs were thought-out, deliberate, responsible, or extensive enough concerning engineering ethics. Little to none seemed to monitor coverage of ethics, and many departments (even department chairs) were unaware of how their program encourages ethical-professional development. Impressions of spotty, random, and undeliberate ethics coverage were consistent throughout the nation’s top engineering schools (Colby, 2008).

The impression of the importance of ethics is severely weakened by the standards of grading imposed on ethical education. Students are not held responsible for understanding and applying the material, and this sends the message that these issues are not as important as the technical ones graded with more care. Engineering students, in a major infamous for being demanding and time consuming, will consider ungraded assignments as superfluous when time pressures are intense. With fewer exams and projects than their engineering courses, students will treat ethics courses and their respective work as effortless and therefore meaningless (Colby, 2008).

Many of the faculty who are not experts in engineering ethics understand the content of ethics modules to be especially personal and subjective. These professors ignore how humanities faculty frequently evaluate students’ work and provide feedback for how to strengthen their presentations, projects, and papers (Davis, 2012). Another concern is the difficulty in grading students on their knowledge and ethical abilities instead of their character and beliefs. A few scoring rubrics have been developed to mend these concerns, and research has backed their
validity as good measures of ethical reasoning about engineering dilemmas (Colby, 2008).

Another major difficulty is current engineering faculty are products of an ethics-deficient curriculum, so teaching ethics with this void is a seemingly daunting task (Newberry, 2006). Newberry claims if ethics education was emphasized at the graduate level, it would undoubtedly become more important in the undergraduate curriculum. Professors often complete their doctoral programs without a single ethics course, and generally participate in research without having to “pay much attention to the social and ethical ramifications of that work” (Newberry, 2006). If faculty were expected to consider the societal and ethical implications of their research, students would likely follow with their own engineering work.

The sources of the problem in engineering education can be summed up in three different, but related, issues. Codes of engineering ethics do not adequately prepare the engineer for making ethical decisions. ABET requires ethical understanding for their accreditations but does not provide any structured methods of implementing this requirement. Finally there are many examples of attempts to educate ethical thought to engineering students, but these programs remain weak because of lack of support from faculty, students, and previous curriculums. Therefore, reform is clearly needed to provide a robust engineering education and teach students the ethical understanding and decision-making skills society requires of the engineering industry.

**Approaches to Ethics Education**

Many engineering programs include at least two approaches to teaching ethics. The most common approaches are stand-alone courses, brief discussions of professional responsibility, ethics within engineering classes, and modules of engineering ethics and professional responsibility within the engineering curriculum.

The philosophy or humanities department generally provides stand-alone courses within the school itself. Ethics outside of engineering has the ability to provide perspectives larger and broader than those constrained by the window of engineering applications. Stand-alone courses provide practice thinking about moral problems and their applications, but there is a serious risk students may isolate the material to just their philosophy course, and many fear that students will not be able to identify a relationship between these ethical ideas and their own problem sets and design projects (Colby, 2008). Texas A&M University implemented a required course in engineering ethics (Herkert, 2006). At the North Carolina State University, an engineering ethics course was added under a general education requirement named Science, Technology, and Society Requirement (Lynch, 1997). Creating ethics courses from scratch can add an additional degree of complexity because these courses have to be built in to the entire curriculum of an engineering department (Engineering, 2013). The second and third approaches are styles of implementation for an across-the-curriculum style of teaching.

The across-the-curriculum model addresses the limitations of required courses and teaches ethics along with technical abilities (Herkert, 2002). Ethics across the curriculum is a program developed by professors in the late 90’s in an attempt to push for ethics education
alongside technical education. These professors argue the most effective way to teach ethics to students is to include ethics lesson within technical lessons, as that is how situations appear in the real world (Kalichman, 2010). For example, the University of Michigan's engineering program implemented an approach to engineering ethics across the curriculum. The university also added numerous courses specifically in ethics engineering (Herkert, 2006). The Massachusetts Institute of Technology has included ethical analysis for all of their major engineering design classes (Lynch, 1997). Previously at Denver University, there was a course named Economics and Ethics for Engineers required for engineering students. However, after the implementation of the new ABET criteria, the university removed that course from its curriculum and implemented ethics modules for the common curriculum used throughout all 4 years in the engineering program (DeLyser, 2011). Grand Valley State University has developed a unique system for engineering ethics in the curriculum for their engineering program. Along with ethics requirements, the program requires a total of 1500 hours of co-op experience. During the co-op, students are assigned book reports addressing ethical and professional conduct. Students are also assigned a case study based on engineering student experiences. They are required to answer questions on the case study, and these studies force them to think critically about ethics and reference professional codes of ethics. At the end of each co-op, there is a mandatory discussion group students must attend to discuss their ideas on the case study with faculty members. This method allows the school to incorporate real-life experiences and ethical issues encountered in the workforce. The program also offers volunteer community service projects highlighting ethical and responsible actions as a member of society (Fleischmann, 2004). It seems the school has structured their curriculum to make ethics central to engineering, and it has been argued this method should be used to teach engineering ethics in other schools (Monzon, 1999). By creating an environment where students are constantly thinking about ethics, the school forces student to realize the importance of ethics in engineering, and this will help them make ethical decisions in their careers. Many educators agree that similar approaches are effective and engaging ways of teaching ethics. (Bucciarelli, 2008).

There are various teaching strategies for use in engineering ethics, and some of these can be used together or interchangeably. A professor can teach ethics using professional codes, ethical problem solving heuristics, or case studies (Moore, 2010). By teaching professional codes, the professor instills in his students the standards to which all engineers are held. However, this is not enough to fully encompass a strong education in ethics. It does not help the student to approach very specific situations beyond the scope of a generic code (Davis, 1999). Ethical problem solving heuristics involves using formulas to arrive objectively at an ethical solution, however not every situation can be quantified using formulas. The most optimal strategy would be to combine these strategies and take the most important factors from each one. However, this can be difficult because of the time constraints of classes and a lack of emphasis on ethics education (Herkert, 2002).

The most common pedagogy of teaching engineering in the previously mentioned methods is case studies and discussion. Case studies should include documented descriptions of
engineering scenarios with ethical components. It is less time consuming for the professor to assign case studies, and these studies open students’ minds to the real world outside the classroom (Herkert, 2002). The more frequent, realistic, vivid, and well-told stories tend to have the most impact on students. Unfortunately, this approach does not have students consider the “trade-offs involved in actual engineering decisions or with the fact that the consequences of those decisions become clear only in retrospect” (Colby, 2008). One other problem with case studies is they do not require the students make any decisions; they only ask students to analyze problems in retrospect. Because of this, case studies alone do not fully prepare a student to make their own ethical decisions when the time comes (Moore, 2010). Thus, short introductions of case studies are not adequate for students to understand the potential problems or complications of ethical decisions in the real world. A less common approach is to have students develop the cases themselves instead of merely reading and learning of others’ mistakes and failures. In this approach, they can become comfortable with the applicable engineering code of ethics, analyze the faults and roles of many factors involved, and “grapple with the issues of responsibility and both moral and legal culpability” (Colby, 2008). In doing so, students undoubtedly will gain a more applied and deeper understanding. It is worth noting the difficulties of various loyalties (to themselves, to their coworkers, to their management) were mentioned in case studies only in engineering ethics courses, yet their presence outside of these specific courses was minimal or absent.

In addition to case studies, service learning (or community-based learning) has become increasingly popular over the last decade. It considers a broad span of outcomes, including “ethical awareness and sophistication” which is fundamental in addressing the dilemmas encountered throughout engineering. When done correctly, service projects are difficult and well woven through the course’s objectives. Many studies indicate that students who participate in service learning projects reap academic and civic benefits. Often found in design classes, service-learning projects, as opposed to generic project-based learning, uphold many aspects of ethical, social, cultural, and professional responsibilities. Although service learning is a fundamental building block for teamwork, students were rarely taught the key “dimensions of professionalism entailed in success teamwork”, specifically fairness, honesty, sense of responsibility, respect, and trust (Colby, 2008).

According to Alfred and Chung, the traditional methods of case studies, dogma and heuristics are difficult to translate from classroom environment to real world ethical situations. They argue a more effective way to provide the training needed to bridge this gap is through experiencing actual situations involving engineering ethics. Unfortunately, it seems unrealistic to simulate these situations in the classroom because it will not have the same effect as a person dealing with the situation at their own job. In addition, academic or corporate entities may not have the resources available to provide actual ethics rich situations to dedicate to engineering (Alfred, 2006).

A unique approach, Alfred and Chung describe an “Interactive Simulator for Engineering Ethics Education”, where students learn how to think about, identify, and respond to these
situations. This allows students to take an active role in ethical education instead of merely listening passively. The simulator consists of four different modes: instructional, training, scenario, and evaluating modes. In the instructional mode, users are presented with core information about the codes, rules, and professional obligations of engineering ethics. During training mode, students are introduced to scenarios which require the recognition of and response to the material. They must assess the situation described and choose the best of several immediate courses of action. In the third mode, scenario mode, users are given a first person perspective to various scenarios involving many engineering ethics situations. Using the information learned from the first two modes, users independently assess the situation and make decisions. Finally, evaluation mode provides an engineering ethics exam, a means to objectively assess the users’ ability to apply engineering ethics (Alfred, 2006).

Potential Solution

Given this research, it is clear that ethics lectures be an inclusive activity. It is ineffective for a professor to simply stand in front of the class and lecture on ethics. A professor must engage the students and attempt to interact with them through role-playing and discussions. By viewing others’ actions in ethical dilemmas, a student can learn how to react herself (Handelsman, 2011). In teaching ethics courses to students, there should be a minimum of these four desired outcomes: an increased ethical sensitivity, an increased knowledge of relevant standards of conduct, an improved ethical judgment, and an improved ability to act ethically (Davis, 1999). As mentioned before, a major resource available to professors is case studies. There are many repositories, but some can be hard to find, and it takes time to find and evaluate case studies that apply to the material in a given class. However, through organizational work by students, case studies from repositories such as the Online Ethics Center (Engineering, Online Ethics Center) and National Institutes of Health (Health) can be very useful resources to professors. These websites contain vast amounts of case studies and information on the education of ethics. Using these resources correctly could greatly improve ethics education in universities. Furthermore, turning a purely technical engineering assignment into an assignment that forces the student to look at ethical aspects can be another effective tool to engage the student (Davis, 1999).

It is clear from this research that students require a better understanding of ethics in the engineering curriculum. Many different approaches have been considered and analyzed for teaching ethics. All have advantages and disadvantages to their implementations. With all these models, there is no one clear answer to an optimal teaching method; however there is evidence that some methods work better than others (Moore, 2010). Two possible solutions are creating a stand-alone course or introducing a greater amount of ethics related topics into engineering classes. Based on the research, the second option appears more viable and many resources are available to apply to engineering curricula. An across-the-curriculum method will be most effective. The outcome will be engaging lectures and projects that allow students to learn how to think ethically with the goal of improving their future ethical decision making as engineers.
Methods and Materials

The overall goal of this project is to improve ethics education in the university setting. However, due to the scope and time constraints of this project, the overall goal cannot be met within the project’s limited timeframe. Therefore, the specific goal of this project is to research and create a tool which will allow educators to implement ethics education into an engineering curriculum. Such a tool should fit the criteria of being easy to implement while also being engaging to students and educators.

From research described in the background, it is clear that students need an enhanced recognition of ethical issues and to have the ability to make decisions on these issues in difficult engineering problems. There are many approaches mentioned in the background for ethics education in engineering. These methods include case studies, across-the-curriculum integration, standalone courses, and role-playing. We believe the across-the-curriculum approach has the most promise in educational value. Across-the-curriculum integration will take years to implement and perfect, and it requires the cooperation of all the curriculum's professors. This integration has been proven difficult to obtain (Herkert, 2002). The standalone ethics courses are a good way for students to practice thinking about moral problems, but they are not a good way for the students to incorporate this thinking into their engineering topics (Colby, 2008). Role playing is a good method to place the students in ethical situations, but it would not be as effective in large classes because everyone would not get a chance to participate (Alfred, 2006). Case studies expose students to real life ethical issues and help students make a connection between ethics and engineering (Herkert, 2002). For the purpose of this project's direct goal, the method of education should be easy to implement and engaging to students and educators. Therefore, the case study method was chosen as the optimal tool to provide ethics education in engineering.

A plethora of sources cite the importance of case studies for educational purposes. Sources describe case studies as providing a strong base for the students’ education in problem solving and decision making skills (Teaching with Case Studies, 1994). One strength of using case studies is they can provide a simple way to discuss ethical issues (Healy, 1997).

Using case studies requires a good amount of time for proper education and to ensure students understand the importance of what is being taught (The Case Study Teaching Method, 2014). There are many resources available with methods for teaching case studies. One in particular, an article produced by Ryerson, gives a very detailed but open to interpretation guide to using case studies for education. No matter which method is chosen, there needs to be a set of goals the professor has for enhanced student learning. First, in choosing cases, the most useful ones are cases that allow for multiple viewpoints (Schwartz, 2012). These cases must be clear and concise because of the time constraint on including these case studies with normal lectures, and time should not be explaining very complex problems so that students understand the case (Teaching with Case Studies, 1994).

Getting the class actively participating is very important, but, because of class time constraints, work will have to be assigned to students outside of normal class hours in order to
achieve the desired outcomes of an improved ability to analyze ethical issues and an understanding of them. First, students need to understand how to work with case studies. For an introduction, using a simple case study and going over the basics of analysis with them in class will provide them with a background in analysis methods. It is important to make certain that students understand there may be multiple possible conclusions in many cases. A student must be able to analyze a case to be able to fully understand it. The “how to” skill will be useful to students in the future because they can analyze their own problems (Teaching with Case Studies, 1994).

Because of the time constraints imposed on implementing ethics education into an engineering course, case studies provide a powerful education tool. They can be implemented quickly and effectively, but also engage students if the case subject is relevant to their education. Based on the research provided above, we concluded that case studies will be a useful tool for professors to use in teaching the ethics abilities of analysis and understanding. They allow the professor to engage the students in debate without sacrificing too much class time normally dedicated to engineering. Given the limited use of class time teaching ethics, case studies are the most useful tool for professors, and will improve students’ ethical skills. Our approach was that we designed two case study teaching methods and implemented them in one course to get feedback from students.

**Design of Case Assignment One (Point/Counterpoint)**

After analysis of the background information and documentation cited above, a consensus was found among sources that one way to educate students on the debates of ethics is to force them to defend either side, or multiple sides of an argument (Schwartz, 2012). An eye-opening article, Listen Up, discussing the loss of sign language due to improved hearing aids for the deaf, was one inspiration for the design (Listen Up, 2013). The article argues the culture of sign language will be lost if technology allows for all people with deafness to gain hearing. Although many would agree that it would only be beneficial to cure deafness, the article presents thoughts from the opposite perspective, and it opens the mind to understanding how culture loss due to technology could be a bad thing. This example demonstrates how having an open mind in terms of ethics allows a student or professional to act in a more analytical way. If they can see all arguments and merits to an argument, they can put personal bias aside and work through ethical issues in a more effective manner.

Based on findings stated above, an education module was developed to enhance students’ learning. Many ethical decisions are based on personal beliefs and biases. In an engineering setting, there is another level of complexity beyond personal ethical standards including how a project or experiment is carried out, and how its products affect society. In designing a module to teach students how to better analyze ethical issues, it was decided that forcing the students to argue against themselves would be an effective manner to engage them and open their minds. This was done simply by assigning students a case study and asking for their opinion. The students were asked to analyze the situation and give their solutions to the ethical issue. After a
discussion and debate in class, the students received their next assignment using the same case study. This next assignment was to now analyze the case study, and provide an argument for the opposite solution to what they previously proposed. This forces the students to argue against their biases and look at the situation from a different, and more neutral, perspective. They must provide an argument and solution to the case study that opposes their original views, and they must back this argument with valid evidence.

This method for teaching with case studies is important because it provides the students with a platform to see situations from different perspectives and create multiple arguments so that all bases of an ethical issue are apparent. In using this method, a useful case study consists of an issue which has two main arguments easily reduced to a pro/con type of situation. The case study will present a problem with ample details to supply both sides of an argument with evidence and reasoning for various solutions. As the complexity of the case grows, so do the number of different arguments that can be made. For this type of assignment, a simple case study can be more effective in creating a two-sided debate.

**Design of Case Assignment Two (Analysis Method)**

For the second case study assignment, a six step analysis method was developed and given to students to apply to a case study. The method allows the students to determine the ethical issues that it poses, present possible solutions to these issues, and decide the best solution (See Appendix D). This six step method was adapted for the assignment from various sources encountered in the research (Corey, 1998; Duncan, 2009; Hamilton III, 1990; Jersey, 2001). The first step involves identifying the ethical issues in the case study, the stakeholders, and basic information for each issue. The next step is to identify and present possible solutions for each issue. Afterwards each possible solution should be analyzed for its the pros and cons along with how the stakeholders of the issue are affected. Arguments for each issue will be presented to show how it will solve the issue and the reasoning behind it. Each possible solutions of each issue should be compared to each other to determine which is most feasible, benefits the most, and is the most morally acceptable. The final step is picking the best solution based on this comparison. The reasoning behind the choice should be stated using answers from previous questions along with a counter argument to possible opposition.

The goal of this method is to give students a systematic way to analyze a case study for the ethical issues and make decisions to solve them. For complex case studies, there might be many ethical issues to address and applying this analysis method for all of them is time consuming. If under a time constraint or pressure to reduce the workload, this method entails, students can be assigned to complete a portion of the method. The students should identify all of the issues for the case study for step 1. The students will then be instructed to apply steps 2-6 for just one of those issues. This will allow the students to use the full process of the analysis method at least once, so they know how to use it in the future. After the analysis is complete, the students will discuss the issues they found, their chosen solutions, and their reasoning for these solutions in class. Discussion is an important aspect of teaching ethics skills, and participation is
crucial. Class discussion allows the students to see issues and solutions that they may not have thought about (Teaching with Case Studies, 1994). In order to test the effectiveness of this method to a control experiment, the students can be asked to point out all the ethical issues they can find in a case on their own and provide solutions. The same assignment can then be given again, but with students performing and showing their analysis using the 6 step method.

**Designing and Using Case Studies**

A case study can be created from many different sources. Of course, there are case study databases; however, a case study can be from any situation or article that poses interesting issues for analysis. For example, the case study used for assignment one in class was derived from an experiment conducted in a laboratory. The report details the execution of a running test. In one test, an athlete sprained his ankle, and the data, after examination, showed the accepted model for ankle sprains may be incorrect. The researchers found that the ankle sprained differently than previously proposed. From this article, an ethical question was created in which your boss has asked you to continue the experiment with the goal of observing more ankle sprains for increased amounts of data for analysis (Fong, 2009). This statement introduced an ethical issue and directed the article from a purely academic article into an ethical case study. To see the full case study given to the class, refer to Appendix A. Case studies can be found in online databases such as Online Ethics Center or Ethics Education Library. These are just two of many resources found online where case studies on any subject can be found. For very specific classes, it can be difficult to find specific relevant case studies. An example to solve this problem comes from case study assignment 2. The basis for the case study was an article explaining the Depuy ASR metal hip implant. There were major problems with the implant and many ethical issues and debates are presented in this article. This article served as a base to form a case study assignment. With clear instructions to focus on ethical issues, many articles can be seen as case studies. One major key to picking a case study is it needs to be interesting to students, and it cannot be one sided. If the case is non-polarizing and most students choose one side of the argument, it will not be very effective for discussion. However, if the case allows for different views and debate, it will engage students more, and thus the education would be more effective.

**Setting for Testing Case Study Methods**

The planned setting for testing these proposed case study methods was a senior level biomedical engineering class at Worcester Polytechnic Institute, BME 4504: Biomechanics. The class took place from January of 2014 to March of 2014 and is a three-credit course taught by Professor Kristen Billiar. The course is offered every other year and is mostly comprised of junior and senior level students. Eighty students were educated mostly on biomechanics; however, Professor Billiar included a section of the class curriculum about related ethics topics. The goal of adding this section is to help improve the ethics understanding and ability of students in the Biomedical Engineering Department. The case study methods were tested in the class by Professor Billiar at various times during the class. The setting of this class for case study
experiments provided a constraint on the project. There was a limited amount of time within the curriculum with which the case study methods could be used. This constraint led to the design of two case assignments (See Appendices A-E) that were efficient in using available class time and required students to work outside of the class as well.

**Implementation of Point/Counterpoint**

Point/Counterpoint was implemented in the classroom setting described above. The full assignment can be seen in Appendix A. The main objective of point/counterpoint was to force the students to defend both sides of an ethical argument. The case study used in this assignment discussed ankle injuries and the debate of human testing. Using the case study seen in Appendix A, we split this assignment into two parts. The first part of this assignment was a small 2 question survey with a purpose of understanding the students’ exposure to ethics and their opinions on topics involved in the case study. The students then received the case study and were asked to give their opinion of the ethical issue presented by the study. These two small assignments made up part one, and were handed in together for grading. The grading policy for these assignments was based mostly on participation, and whether the assignment received proper attention to detail. After the assignment was handed in, the professor held a small, twenty minute discussion in class, allowing the students to guide the direction of the debate. The students defended their positions and the professor acted as a mediator during the discussion.

When the discussion ended, the professor introduced part two of the assignment to the students. The final part required students to now defend the opposite argument with which they previously defended. This method forces the student to go against their own opinion and opens their mind to the possibility of other arguments being the correct solution. The students were required to write one paragraph defending the opposite argument. After the assignment was completed, the students were then asked to fill out an eight question survey (seen in Appendix B) to obtain results on how effective the method was and for the reactions to the assignment.

**Implementation of Analysis Method**

Analysis Method takes a more analytical approach to analyzing a case study. The students are provided with a 6 step case analysis method which they can use to interpret a case study (Appendix D). First they will be provided with the case study for this assignment. The case study is comprised of multiple articles discussing a novel metal hip implant created by Depuy. These articles discuss the product as well as multiple views debating regulation and the FDA. These articles serve as the base for the case study, by directing them to debate the FDA and the ethics involved in implantable products. This assignment is also split into two parts. The professor introduced the 6 step method for case study analysis and went over a simple example on how to utilize the 6 step method on the case study from assignment one. The students are instructed to read the article and use the 6 step case study analysis method to analyze one issue from the case study (Appendix C). After the assignment has been turned in, the professor will then have a discussion in class highlighting topics and mediating debate among students. The 6
step case study method is very in depth, and allows the students to visualize multiple facets of an ethical debate. It allows them to construct multiple arguments that help the students use these arguments to decide on a final solution. After this assignment was completed, the students were then asked to fill out a survey in order for us to gauge their reaction to this assignment and to compare its effectiveness with that of point/counterpoint (Appendix E). This survey will provide useful results that can be used to validate the usefulness of this case study method.

Implementation of Point/Counterpoint in Professor Jain’s Class

The point/counter point method was further studied in BME 483X: Drug Delivery. This class is taught by Professor Anjana Jain and is a senior level biomedical engineering course. For the purposes of this experiment, professor feedback was the most important take away from this study. Professor Jain graciously volunteered to perform the point/counter point method in her class, but tweaked it for the purposes of her class. She was asked to design the assignment and carry it through completion. The designed assignment can be seen in Appendix F. This procedure provided data on ease of implementation for the professor. The class was assigned to read an article pertaining to compassionate care (Sanghavi, 2013). The assignment then directed students to first define compassionate care, then outline the two sides of the argument, and finally pick a side and defend your reasoning. The assignment was turned in and a debate followed in class with students stating their opinions and arguments for each side. As students debated their topics, the professor and TA wrote the arguments on the board, allowing for visualization of each side of the argument. When the debate finished, the professor asked the students a few questions to gauge their response to the assignment.
Results

From the research and design of Point/Counterpoint and Analysis Method, the two modules were implemented in Professor Billiar’s Biomechanics class. The two modules were executed in different lectures.

The Biomechanics course grade contained a five percent ethics component, four of which were attributed to these two assignments. Two of the percentage points were for completion of the arguments for the point counterpoint assignment. The remaining two points were attributed for the completion of the analysis method assignment and its corresponding survey. To receive the full point, the student was only required to demonstrate that they went through the entire method, not having a correct or specific answer.

The main results extracted from these two case study assignments are the surveys filled out by participating students. They offer insight into improving the design of the case study assignments and provide feedback on effectiveness of the two modules.

Assignment One Survey Results

Assignment one was delivered to the students in a two-step process. In the first part of point-counterpoint method, the students needed to offer their opinion on a controversial topic and provide defense. The second part of assignment one required students to conjure up an argument that defended an opposite argument they previously presented (in Part one). Both of these responses were analyzed statistically to understand how effective the assignment engaged the students in learning.

From argument one of the assignment, we found that students were split on the controversial decision, with 35 students choosing one argument, and 36 defending the opposite argument. These polarized results are seen in Figure 1 below. This statistic is essential because it shows how the case study was polarized and thus, the class was evenly divided. Furthermore, the students’ responses from the counter-point section were compared with point-argument. The word count for their opinion was 174 ± 56 words. The word count for argument two, through which students defended the opposite argument from their original, was 142 ± 55 words. Because the standard deviations are similar, we can directly compare that on average, the first assignment was about 30 words longer per student.

![Figure 1: Pie chart of student's viewpoint on human testing](image_url)
Out of the 79 students in class, only 35 filled out a survey. However for the graded assignments, the response rate was 94%. Table 1 below shows the results of the response rate. Based on student feedback, a majority of the students liked the point-counter point method. The method allowed students to see the pros and cons, thus they were able to see the dilemma from more than one perspective. Multiple perspectives helped students choose a side based on logical reasoning. The students also felt that this method reduced reliance on bias in their arguments. For some of the students, having an awareness of both sides helped strengthen their initial argument.

Table 1: Response rate and grade distribution for point/counterpoint

<table>
<thead>
<tr>
<th>Assignment</th>
<th>Response Rate</th>
<th>Grade Given</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Argument</td>
<td>94%</td>
<td>1%</td>
</tr>
<tr>
<td>Counter Argument</td>
<td>94%</td>
<td>1%</td>
</tr>
<tr>
<td>Feedback survey</td>
<td>44%</td>
<td>0%</td>
</tr>
</tbody>
</table>

From questions pertaining to necessary information and suggestions, some students felt there was not enough information provided in the case study in order to make a decision on the correct plan of action. For the specific case study given in assignment one, students asked for the consent form given to participants in the study, the data presented by the experiment, the number of participants, and the details of how the experiment was run. However, included in the assignment was a link to the full report of the case study, showing that some students did not take the time to read through the report for more details, instead reading just the summary. More than half the students wished to see the waiver form for volunteers, with their opinion hinged on its contents; unfortunately this was not presented in the report. It is possible that one could have been made up for the purposes of this project. However, having a waiver did not seem to hinder discussion of the case’s issues, only decisions on solutions, suggested the student feedback. Most students were in agreement that they were still able to make a decision on the issue. Furthermore, some students also cited that a more controversial case study and longer class discussion were preferred. One interesting suggestion was to begin a debate with very obvious case of blatant disregard for ethics, and then work the discussion toward the more grey areas of the debate.

As seen in Figure 2, 80% of students retained their viewpoint on the controversial issue, with 20% saying that their viewpoint had been changed in some way on the topic, either by switching sides or finally picking one. However, many of the students cited that they would pay attention to ethical dilemmas in engineering and this type of situation more than before the debate. When asking the students if they felt they gained any knowledge in ethics, we find that many students had major takeaways from the debate. One student’s answer stated, “It is important to understand the many decisions that occur in the design process, particularly related to testing. You must choose who, what, where, when and why very carefully and be able to back your decisions every step of the way in order to prevent or plan for those negative consequences that may occur due to testing”. Many students further backed the above statement by saying that
they felt they now understand how much detail goes into the evaluation of ethical issues and
decision making associated with them. Some also cited that they developed the skill of playing
devil’s advocate. They stated that this skill will be useful in helping to defend their own
decisions.

Figure 2: Pie chart of whether or not students changed their viewpoints after point/counterpoint

Assignment Two Survey Results

The second case study assignment students were given a case study and using the six step
analysis method, reasoned the ethical considerations involved in that study. After the task was
completed, the students filled out a survey for feedback and the results were conclusive. The
response rate for this feedback survey was 92%, which is much higher compared to the response
rate of the first assignment. Overall, the students wrote much more for this assignment than the
first assignment with the point-counter point method. The analysis method required the students
to do a more in-depth analysis of the case study, which we speculate increases the response
length.

Table 2: Response rate and grade distribution for Analysis Method

<table>
<thead>
<tr>
<th>Assignment</th>
<th>Response Rate</th>
<th>Grade Given</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analysis Method</td>
<td>92%</td>
<td>1%</td>
</tr>
<tr>
<td>Feedback Survey</td>
<td>92%</td>
<td>1%</td>
</tr>
</tbody>
</table>

As indicated by the survey responses, a majority of the students like the case study
analysis method. The method allows the students to do a more thorough analysis and thus helps
identify more ethical issues than by using discussion alone. Many students even indicated that
they were able to find more ethical issues that they had previously missed with this new method.
Students felt that the analysis method helps them organize their ideas more easily and keep track
of all the ethical issues. The students noted that the method made a complex ethical issue less
overwhelming to dissect. Of the students surveyed, 79% said that they would definitely keep a
copy of the analysis method and use it later on in the future, as seen in Figure 3.
Many found that they were able to complete the analysis without deliberately letting their bias cause their analysis to be ineffective. Some were unsure if their bias or the bias of the case study authors caused them to subconsciously miss some of the factors presented in the case study's situation. As a result, several students felt that the analysis method was unsuccessful because of the bias. Many indicated that the analysis method lacked some resources needed to complete all of the tasks it called for. The first deficiency was identification of ethical issues present in a situation: the method did not help them find issues. The second concern was in the selection of solutions: students felt there was not enough criteria for selecting solutions. As a result, some students specified the final solutions that they chose for the ethical issues were picked because of their personal moral values.

Some of the students felt that the analysis method was time consuming and repetitive. Suggestions were made to combine some of the steps of the analysis method together (Steps 3 and 4 as well as Steps 5 and 6). Students believed this would decrease repetition in the analysis method. When asked if they liked the analysis method or the point-counter point method more, students could not really say. They favored both of the methods that were given to them in class and noted that both methods were useful in different ways. Students recognize that the point-counter point method was more useful for a small, simple case study with a single ethical issue. The analysis method was fit for the complex case studies with various ethical issues. However, some students did state that they liked the point-counter point method better because it was easier to do and took a lot less time compared to its counterpart analysis method.

**Feedback from Professor Billiar**

Feedback from Professor Billiar was obtained on the assignments that were implemented
in his class. Overall, he felt that the case study assignments were useful in getting the students thinking about ethics. The discussions for both methods took about 30 minutes. Prior preparation for the point/counter point method took about an hour while preparation for the analysis method took about two hours. The professor felt that the point/counter point method was easier for students and required a lot less work compared to the analysis method.

Results of Implementation and Feedback from Professor Jain

From the results of the assignment implemented in Professor Jain’s class, it was apparent that the debate was very polarized and students were not wary to provide their own opinion in the debate. The idea to write out arguments on the board was also a very useful addition, which will be made part of future design ideas. After the debate, students were asked whether they felt their mind had been changed on the topic; however no one acknowledged that their mind had been changed by the debate. Feedback from Professor Jain was provided through oral communication. She felt that the class debate went very well and that her role as a mediator was simple because of the very polarized debate in class. Furthermore, she only required about half an hour to design the assignment, and 50 minutes of in-class time for the debate. The most important result is that Professor Jain said that she will continue to include ethics assignments in future classes.
Discussion

Grades and Response Rates

From the results, we can see that professors do not necessarily need to allocate high percentage of the student’s final grade for ethics in their courses. The response rates for point/counterpoint and analysis method were 94 percent and 92 percent respectively. For point/counterpoint, 1 percent of the final grade was given for the initial argument and another percent for the counter argument. There was no grade given for the feedback survey for assignment one and the response rate for that was 44 percent. For analysis method, 1 percent of the grade was allocated for using the analysis method for the case study and one more for the feedback survey. For all assignments valued at 1 point out of 100 for the final grade, response rates were above 90%. However any assignment not given a point value held a response rate below 50%. Just one percent of the grade for an assignment can yield a response rate of over 90 percent, as opposed to a response rate of less than 50 percent for a voluntary ungraded assignment.

Understanding Student Feedback

When comparing the two case study methods implemented in class, it is clear both have their merits. Students recognized that the point counter point method was better to use for simple scenarios with a single ethical issue. Students felt the analysis method was useful for a more complex case with multiple ethical issues. Use of the analysis method allows students to organize their ideas and think through the ethical issue in a systematic way. The analysis method assignment showed that students took their time to analyze the case study to find ethical issues. The point/counter point method lets students see the problem from both perspectives. It is interesting to note that the students wrote more for their initial argument compared to their counter argument. This observation indicates students may have been more passionate about their initial opinion. However, the difference between them is not very significant. From our results, 20 percent of the students changed their viewpoint after using the point/counter point method. Changing their mind shows that all other options were considered. This shows that the method was successful in engaging the students to think about the problem fully and resulted in a more informed decision. Overall, both teaching methods were engaging enough to promote awareness of ethical issues found throughout engineering in the classroom.

The discussions included in both case study methods were beneficial for the students. Students note that the dialogues for both case study assignments help them consider the opinions of other students. For some, it allows them see more points to support their initial argument. For others, classroom discourse introduces them to the reasons behind support of the other argument. Therefore, the discussion for the case study analysis method aids students in realizing ethical issues that they might have missed from just doing the assignment without the feedback of others.
Based on the student response, both of the case study teaching methods can be refined. During the discussion, students simply stated their opinion to the professor. The discussion for the point/counter point method can be improved instead by having students debate their opinions. This change would allow for the students to get more awareness on the different ethical views on the discussed ethical issue. Debate also gives students the opportunity to practice their professional argument skills, as well as react to having their ideas challenged or strengthened by peers.

For the case study analysis method, students suggest that a few steps could be shortened and/or combined. Steps 3 and 4 (in which students were asked to analyze and construct arguments for each solution) could be combined to a single step. The proposed step would include instructions to construct arguments and to look at the pros/cons of the each solution. Also, steps 5 and 6 could be cut down to have students choose a solution and explain why their choice is the best. However, these changes are mostly for aesthetics in efforts to reduce the number of steps. Students will be doing the same analysis even though the number of “steps” are decreased. Some students stated that the analysis method was long and repetitive; the analysis method aims to help students build their arguments through the progression of each step, thus the steps are thorough. Also, 79% of the class noted they would keep the analysis method to use in the future which shows that the length of the method did not cause a considerable negative reaction.

**Students Understanding of the Role of Ethics**

Another concern from the feedback on the analysis method was the students’ confusion of the definition of ethics and its specific role in engineering. Many students reported different understandings of what ethics is: the study of bias, the study of philosophy, or the study of opinions. This confusion led to many levels of learning outcomes. Some found the assignment greatly useful for allowing them to comprehend ethical issues, while others found it useless due to these preconceived notions of ethics. The students’ misunderstanding of the definition led to disconnects in understanding the value of the assignment. Thus, there is a wide distribution of what ethics means to students. Some of these views are counter-productive to the goal of increasing awareness of social implications from engineering work. Therefore, in order to improve the teaching of ethics in engineering, it is suggested that students are taught this true standard meaning of ethics, how it relates to engineering, and how to work with it to be successful.

**Analysis Method Improvements**

In the analysis method assignment, students noted three major topics missing guidelines. As noted above, these are: dealing with personal and information source biases, analyzing and deciding between choices of moral problems, and identifying ethical issues.
Handling Bias

In the analysis method, students felt that personal or information biases defeated the point of the assignment or made it impossible to complete. Many of these viewpoints were linked to the comprehension of ethics as inherently having bias or being the study of bias. For the other students, bias made them incapable of capturing all ethical issues or having a correct analysis. Due to this lack of confidence, we assess that the analysis method requires more guidance and structure in handling bias. A potential addition to the analysis method would be instruction on how to work with an awareness of bias and analyze biased sources.

Instruction on bias awareness could be as follows:

For each ethical issue, think about how you initially feel about the issue and what you believe should be the solution. Record this bias for use in your analysis. As you analyze each ethical issue and search for information, periodically compare your findings to your bias. Be sure that your bias is not causing your analysis to reflect your feelings. Check that you are not ignoring information that goes against your bias. Go back through the situation and purposely look for information supporting the opposite opinion of your bias, in order to find any information you skipped.

This set of instructions could be refined through research into human bias. This would allow the instructions to be more useful in the methods of identifying one’s own bias and preventing it from influencing one's analysis. When dealing with a biased source, the following could be used as an instruction:

For the sources used in your analysis, check if they contain bias. To do this, check if the information presented is already directed to a specific answer, or if it is an opinion. This does not defeat the validity of the source; it only requires a closer look at the information from that source’s perceived bias. Record the bias of the author of each source and compare that to their conclusions. Be sure that they have enough support for their conclusions and that their arguments are formed just on their bias. Additionally, derive all unbiased facts you can from the source and if needed, pursue additional sources that are unbiased or differently biased.

This set of instructions could be refined by research to include ways to identify bias in a source. This identification of bias would include an analysis of the argument’s fallacies and an examination of arguments for biased support as opposed to factual support.

Moral Choices

The moral choice problem in the analysis method's instructions is evident from the student survey. While students were able to see the implications in ethical issues, they lacked the ability to determine a solution. This is because the students were faced with a problem of morals
at the end of their analysis. For example, in the point-counterpoint assignment, the ethical issue was human testing. With analysis, this ethical issue is broken down to the debate between benefit of many verses the benefit of the individual, a classical philosophical moral topic of debate.

Therefore, to improve the analysis method, instructions should be included to guide the student to judge and decide between solutions that depend on morals. Improvements would require further research into ways to teach how to analyze these philosophical moral dilemmas. This ability would allow the user to judge these solutions more accurately despite any moral obligations. Given the current structure, the analysis method allows the user to understand the ethical issues present, and to understand implications of their possible solutions. This will allow them to still think about the ethical issue, and develop reasoning for their actions. Thus, using the current method is still more effective than a solely biased solution.

**Identifying Ethical Issues**

Difficulties for students with abilities to identify ethical issues jeopardized the usefulness of the analysis method. Students were unsure if they had found all the ethical issues in the given case. Many students stated that there was not enough information to find all ethical issues, or any metric to determine that they did find all of them. Several students noted throughout the class discussion ethical issues were identified that they had not considered. This shows the identification of issues aspect of the method was lacked direction and should be improved.

Currently, the analysis method gives the following instructions on identifying ethical issues:

**Identify Ethical Issues:**

- find these by searching for problems that involve moral concerns, have opinionated debate, and or lack concrete answers
- For any issues that are directly linked to other issues, and cannot be separated, treat them all as one ethical issue together

Only the first point gives users instruction for finding ethical issues. Finding these ethical issues are key to analysis and understanding of the ethical implications of engineering work. Therefore, the lack of this guidance in the analysis method is a critical fault for students who do not already have this skill. To improve this, further guidance should be included in the analysis method. This instruction will guide the user on how to decide if something is an ethical issue. Therefore, a potential revised set of instructions could be as follows:

**Identify Ethical Issue**

- find these by searching for problems as follows:
○ Determine what problems the case study presents and what decisions have to be made. Think through these problems and what will be faced in attempting to solve them.
○ Research these problems for other analysis and debate that already exists
○ Analyze the problems of the case study and from the research found for the following criteria:
  ■ moral concerns
  ■ opinionated debate or solutions backed by beliefs
  ■ lack concrete answers

This altered instruction now gives some direction into how to search for problems in order to find ethical issues. It covers how to work through problems to find ethical issues, including thinking through solving the problems for what ethical issues they reach and researching the problems for analysis from more informed perspectives.

Through the addition of all of these refinements the analysis method can be greatly improved in its usefulness. To fully implement them, further research is required. As a final step, the analysis method would have to be implemented and tested in a class setting again, to evaluate the additions and determine any further areas of refinement.
Future Study

Although the IQP group has made significant progress toward our project goal, our job is not done. There can always be improvements made toward a better ethics education within engineering curricula.

Students should have a better understanding of basic skills needed for a full ethics understanding, and for this, concrete strategies should be developed to achieve this. It is likely that research would suggest methods of education of these basic skills. With testing and assessing students using these methods, a couple effective and engaging methods should be developed. Our IQP focused on education to understand specific ethical issues and dilemmas, whereas this would teach the basic skills to do so. In addition, a test to examine individuals’ initial level of understanding is suggested. In the development of this test, professors and administrators would be better able to track the ethical progress of students. With the ability to pinpoint where students begin, they would more easily assess the effectiveness of various teaching methods as students graduate.

Our IQP group has created a handbook; a handbook intended and created for the use of professors and other educational leaders as a useful guide in an effort to bridge the wide gap of ethics skills and a technical competency throughout engineering curricula at WPI as well as other universities. Future Study of the handbook should include the creation of tests to examine its effectiveness, the testing of the book, as well the addition of any suggested and verified improvements. After several rounds of testing and suggestions, a highly usable and effective handbook should be available.

The ultimate goal of our IQP, as well as many other ethics programs, is to develop an Ethics Across the Curriculum model. This can only be done with the encouragement of professors, and eventually their faithfulness to continue our work throughout their classrooms. Using the handbook discussed above as a guide, this will be a reasonable goal.
Conclusion

It is apparent that students do not receive proper education in the study of ethics in engineering. They lack this ability to deal with ethics and to recognize that ethics is part of every engineering decision. This is in part due to a lack of emphasis on ethics education at the university level. Based on literature, an across the curriculum model was found to be a proper pathway to improving ethics education. Within the time constraints of this project, only part of an across the curriculum model was able to be tested. Case studies have been proven to be effective teaching resources for many different facets of engineering, including ethics education. Two case study teaching modules were designed, Point/Counterpoint and Analysis Method. They were implemented in multiple classes in the Biomedical Engineering Department at Worcester Polytechnic Institute. These methods were followed up with student and professor surveys.

Our pilot data indicate that these methods were effective in achieving our goal. With the results of the Point/Counterpoint and Analysis Method modules, we conclude that the students learned valuable skills for their futures. Furthermore, we demonstrate that it is possible to include ethics into an engineering curriculum in an easy and straightforward manner. The experience provided by these assignments is rarely seen in engineering curriculum, but should be more present. Our data show that students were responsive to ethics curriculum and recognized the importance of ethics. With resources presented in this paper, students can build this awareness and be better suited for working in industry. The research and creations of this project have been compiled in to a handbook for educators, for them to implement ethics education into their curriculum. This handbook has been attached to this report, in appendix G. These created methods can help prepare engineering students to make ethical decisions throughout their careers allowing them to uphold and improve the welfare of society.
Works Cited


MedIndia. (n.d.). An Introduction to Biomedical Ethics.


Teaching with Case Studies. (1994). *Stanford University Newsletter on Teaching.*


Appendix

Appendix A: Point/Counterpoint

BME/ME 4504 Ethics Assignment 2 - Human testing

Pre-case study Questions:
1. Have you had past experience with ethics education or case studies? If so in what setting and how often have you been exposed?
2. What is your viewpoint on human testing for biomechanical research? Is it ever OK, and if so, under what circumstances?

Biomechanics of supination ankle sprain: A case report of an accidental injury event in laboratory

Project manager: Daniel Fong
Supervisor(s): Kai-Ming Chan
Co-worker(s): Yosuke Shima, Tron Krosshaug, Patrick Yung, Y Hong
Project status: Published

Descriptions
Over the years, ankle kinematics has been studied during simulated sub-injury or close-to-injury situations, i.e., sudden simulated ankle spraining motion on inversion platforms (Myers et al., 2003). Since these tests did not induce real injury, they could only somewhat suggest the ankle kinematics during an ankle sprain injury. The most direct way is to investigate real injuries using biomechanical measuring techniques. However, it is obviously un-ethical to do experiments where test subjects are purposefully injured, but in rare cases accidents may occur during biomechanical testing (Barone et al, 1999; Zernicke et al, 1977). This study presented an accidental supination ankle sprain injury occurred in a laboratory under a high-speed video and plantar pressure capturing setting.

One male athlete (age = 23 years, height = 1.75m, body mass = 62.6kg) wore a pair of high-top basketball shoe and performed a series of cutting motion trials in a laboratory. The university ethics committee approved the study. The subject was instructed to run forward for six meters with maximum speed, before making a rapid left turn within the capture volume. In the fourth trial, the athlete accidentally sprained his right ankle with a supination mechanism.

The ankle motion was assessed using traditional marker-based motion analysis as well as a model-based image-matching technique for 3D reconstruction.

Results
The analysis showed that the injury situation deviated from the non-injury trials by a sudden inversion and internal rotation after 100-120 ms. Furthermore, the injury surprisingly occurred in 10-20° dorsiflexion. This finding is in contrast to previous hypotheses where a lateral ankle sprain occur in considerable plantar flexion. The prior hypotheses were, however, based solely
on cadaver experiments and not real injury situations.


Link to full report: http://ajs.sagepub.com/content/37/4/822.long

Based on the results, it is apparent that the model for ankle sprain needs to be improved, and the findings in the experiment could lead to an improved model. The current method appears to provide a novel method for studying ankle injuries when they occur in actual athletes. The athletes are paid to participate in the study, and the consent form signed by the athletes indicates that they understand the risks associated in participating in the original study and that the researchers cannot be held liable for injuries that occur. The researchers now know that there is a definite risk of injury, yet continued testing using the same methods could be provide more data to formulate an improved model of ankle sprain if the athletes happen to sprain their ankles during the trial. More human testing may also lead to improved designs to reduce ankle sprains.

Your boss has asked you to continue these tests to study sports physiology and also with the additional goal of better understanding ankle injuries. Would you agree to continue the testing in exactly the same way as planned in the original study? **Write a paragraph on your opinion in the matter including pros and cons. You must make a decision either way - yes or no – and explain how you came to the decision.**
Appendix B: Point/Counterpoint Survey

Human Testing Case Assignment Survey

1. Has your viewpoint on human testing for biomechanical research changed?
2. Was there enough information to create a decision in the initial assignment? If not, what other information is needed?
3. Was the method of point and counterpoint analysis (points highlighted in the paragraph after the story) helpful to understanding the ethical issues present in the case study? How so?
4. How does the method of point and counterpoint compare to just providing your initial opinion, as with the previous engineering ethics assignment?
5. How did the class discussion alter your perception of the ethical choices?
6. Did you gain any further insight into making ethical decision from the follow-up assignment where you are asked to argue the opposite decision?
7. Do you feel that you gained any knowledge or skills about how ethical decisions are involved in engineering decisions from this assignment? Please describe.
8. Do you have any suggestions for improving this case study method?
Appendix C: Analysis Method

BME/ME4504 C14 Ethics Assignment #4 – ASR regulation and recall

Read the posted set of articles “Out of joint_The story of the ASR_ BMJ2011.pdf” then respond to the prompts in blue below. In a separate document, list the same step numbers (and headings as needed) and write proper sentences for your responses unless it is a factual question (e.g., who are the stakeholders?), in which case they can simply be listed. You only need to write out a full paragraph for the last prompt. Please upload as a PDF.
Appendix D: Case Study Analysis Method for Situations with ethical issues

Analysis Method for Situations with ethical issues
This method for analyzing situations with ethical issues (a component of a problem that deals with morality, the concept of right or wrong, and/or social roles) is a form of engineering problem analysis and solving, applied to the concept of ethics.

Sections in blue are prompts for what the assignment requires from each step as a hand in.

Step 1: Identify Ethical Issues
Identify the problems of the situation and what ethical issues are present.

- Identify Ethical Issues:
  - Find these by searching for problems that involve moral concerns, have opinionated debate, and/or lack concrete answers
  - For any issues that are directly linked to other issues, and cannot be separated, treat them all as a single issue
- Identify additional parameters for each Issue:
  - Why this is an issue?
  - Who are the stakeholders involved?
  - Is there any missing or incorrect information?
- List these issues and their parameters

Step 2: Outline Possible Solutions
For each of the found ethical issues, find the possible solutions that can be followed in response.

- Find possible solutions by analyzing the problem and determining ways that it can be solved
  - What are the goals of the issue and how can they be achieved?
  - Check for solutions that have already been proposed
  - Research the issue’s related laws
- Describe these possible solutions

Step 3: Analyze each Solution
For each possible solution to each issue, analyze how it solves the issue and the problem

- Analyze the pros and cons of how the solution solves the ethical issue
- Analyze how ethical the solution is:
  - Note what form of reasoning the option’s ethicality is based on:
    - reasoning methods:
      - societal moral law
      - concrete laws of society
      - benefits and/or drawbacks for stakeholders
- Write out analysis for each solution

Step 4: Construct Arguments for Solutions
For each possible solution to each issue, use analysis and reasoning to create arguments for why the selected solution should be used to solve the ethical issue and problem.

- Create argument and defense:
  - How it will solve the issue?
  - Why it is better than other options?
- Be sure to avoid your own bias affecting your argument or excluding possible solutions from analysis.
- Write out all arguments

**Step 5: Compare Solutions**

For each issue, evaluate and weigh the effectiveness of each possible solution against each other.

- Compare the possible solution arguments to each other, in respect with:
  - The expected outcomes
  - The feasibility of implementation
  - The benefits and detriments to the stakeholders involved
  - Any factual assumptions, missing information, or logic errors
- Write out all solution analysis

**Step 6: Choose Solutions**

For each issue, choose the solution with the strongest ethical reasoning and create a defense for your position.

- Use your answers from the previous steps to pick an optimal solution
- Find areas of possible opposition in your argument and create an argument to counter them
- Write out chosen solutions with reasons why they are the best option.
Appendix E: Analysis Method Survey

BME/ME4504 C14 Ethics Assignment #5 (1 pt.)

Answer the following feedback questions about using this method and upload the PDF.

1. Did the analysis method allow for easier and/or more complete analysis of the complex case than before? Why or why not?
2. Did you find additional ethical issues with this analysis? Now, how certain are you on if you have found them all and why?
3. Has your ability to decide on solutions to these ethical issues improved? Why or Why not?
4. How did the discussion affect your view on what were the best options? Did the analysis method allow you to notice all factors of the situation and did any of your own personal bias affect your analysis?
5. Will you use this analysis method for future ethical issues in your career in engineering? Why or why not? What if the situation is not as complex?
6. What would improve this method so that it would be the most useful?
7. How does this method compare to other methods, such as the point-counter point method of the previous ethics assignment. Do you feel both have merit? Or is one method more effective than the other?
Appendix F: Point/Counterpoint in Prof. Jain’s class

BME483-D14-01 Homework #4
Due: Friday, April 25, 2014
Please read the NY Times article “The Pills of Last Resort - How Dying Patients Get Access to Experimental Drugs”.

The assignment should be 1 page, single-spaced, 1" margins, with font no larger than 11 point. Please make sure to include the following information: 1) What is compassionate use? 2) What are the 2 main sides of view? 3) Choose 1 side of the debate and provide a reasons as to why it is compelling."
Appendix G: Ethics in Engineering Handbook

Peter Lam
Kevin Reyer
Meghan Cantwell
Richard Matthew Rafferty
Engineering Ethics Education Handbook

Richard Matthew Rafferty, Meghan Cantwell, Kevin Reyer, Peter Lam

Contents
Introduction............................................................................................................................................................................. 43
Purpose...................................................................................................................................................................................... 43
Learning Outcomes and Requirements.............................................................................................................................. 44
Strategy Uses and Requirements.................................................................................................................................... 45
Strategy Implementation Guides.................................................................................................................................... 46
  Point/Counterpoint............................................................................................................................................................. 46
  Analysis Method................................................................................................................................................................. 49
Assignment Development Resources............................................................................................................................... 51
  Designing and Using Case Studies................................................................................................................................ 51
  Potential Ethical Topics.................................................................................................................................................... 52
Works Cited............................................................................................................................................................................. 53
Appendix................................................................................................................................................................................... 54
  A: Point/Counterpoint Example..................................................................................................................................... 54
  B: Case Study Analysis Method.................................................................................................................................... 56
  C: Example Student Output for Point/Counterpoint Strategy .......................................................................................... 58
  D: Example Student Output For Analysis Method Strategy .......................................................................................... 60
Introduction

Due to the impact of their work on society, engineers have an ethical responsibility for its safety and welfare. Although codes of ethics, such as the BMES code of ethics, and industry exposure are invaluable in guiding ethical behavior, universities have the potential to provide students with effective frameworks for identifying and navigating ethical situations. Yet many engineers graduate with a lack of awareness in ethics. Two ways ethics education can be incorporated in a university curriculum are through required courses or integrated in courses across the curriculum. Most programs do not have the resources to offer stand-alone courses to all students, thus they must utilize an across-the-curriculum model. However, these efforts are hindered by a lack of resources for instructors of technical courses.

Purpose

The goal of this handbook is to aid instructors in incorporating ethics into an engineering curriculum in an effective and engaging manner. It contains necessary information and resources for implementing case study based ethics assignments. The two focused on are the Point-Counterpoint strategy and the Analysis Method strategy, both developed from research and best practice in the fields of ethics education and engineering. The following pages cover the uses of cases studies and the development of these learning strategies. Further, the learning outcomes and requirements for these strategies are covered. Finally, the guide to implementing these strategies and the resource needed are given.

Preface:

The following work stems from a student project at Worcester Polytechnic Institute. This project is found as a report as an Interactive Qualifying Project. The title of the project is Ethics in Engineering Education.
Learning Outcomes and Requirements

Which strategy works best?

Each of these learning strategies allow for different outcomes from students and have different requirements and situations where they function most efficiently. The question of which works best is entirely based on what outcome is desired for the students and the abilities of the environment they are implemented in. Depending on the desired outcomes and limitations of implementation, these strategies can be decided between.

Learning Outcomes

Point-Counterpoint

The learning outcomes for students in the point counter point strategy are to learn about how to think about an ethical issue and how to create reason based supporting arguments. The focus of the strategy is for the students to learn about one ethical issue, through arguing for both sides to its solution and discussion it with other students. Through doing this the students will learn about the presented ethical issue and how to think about an ethical issue. Students will not have to rely only on their bias and feelings, and instead allow them to expand their viewpoint on the issue.

Analysis Method

The learning outcomes for students in the analysis method are to learn how to break down complex sets of many ethical issues and analyze them for solutions. The focus of the strategy is for students to approach a case study of multiple ethical issues, similar to how they will face problems in their career. Through doing this, the students will learn about the presented complex set of ethical issues and the skills of ethical issue analysis that their future career will require.
Strategy Uses and Requirements

Point/Counterpoint

- Requires only a small amount of introduction time in or outside of class
- Student work is short
- Debate can be done between 20 to 60 minutes
- Each implementation of the strategy works with one ethical issue from the examined case study
- Focuses on teaching basic ethical issue thinking process

Analysis Method

- Requires only a small amount of introduction time in or outside of class
- Student work is long, depending on number of issues examined in case study
- Debate can be done between 20 to 60 minutes, depending on number of ethical issues examined
- Each implementation of the strategy works with one case study of multiple ethical issues
- Focuses on students understanding an entire situation of many ethical issues and teaching ethical issue analysis skills
Strategy Implementation Guides

Point/Counterpoint

Goal of the assignment:

Inspire familiarity with an ethical issue presented in a case study. This will be useful in teaching the benefits of being unbiased in analysis and discussion of ethical issues. Students will develop a skill of looking at both sides of an argument, helping them be more open-minded. For this assignment, an issue will be presented and the students are required to create a supporting argument for both sides as to how to solve the issue.

Implemented Point vs. Counterpoint Example:

A test run of the point counter point method was done in a biomechanics course. Students were given pre-assignment questions before the case study was given to get an idea of their standing on human testing. A case study on a running experiment was given to the students. The case study talked about an athlete who was performing a test where the subject would sprint forward and make a sudden turn afterwards. During one of the trials, the athlete sprained his ankle. The data from the ankle sprain generated different results from what researchers previously thought from data obtained from testing on cadaver ankles. The case study itself did not present ethical issues. However, a scenario was created based on the findings from the article. The students were asked, if they were working for a company and their boss asked them to run the same test to obtain more data to potentially develop a better ankle support to better prevent ankle sprains, would they continue the testing? The ethical issue here is that the researchers intentionally want the subjects to sprain their ankles. After the assignment was completed, a feedback survey was given to students for their ideas on the assignment.

An example of the expected student response can be seen in Appendix C. This example is based from the biomechanics trial run test of the Point/Counterpoint strategy.

Results of example:

From our results, there were 35 students that said they would continue the testing and 36 students who said they would not. After the assignment, 20% of the students changed their initial decision for the case study. The students liked the point counter point method because it allowed them to see the perspectives from both sides of the argument and analyze the pros and cons of each. This allowed some of the students to strengthen their initial arguments. Some students felt that the discussion was helpful in showing them some points that they did not think of initially.
Assignment Development and Instructions for Educator:

Case Study Criteria:

- Pick a single ethical issue to focus on.
- One that is capable of polarity so it will be useful for discussion. (both sides have a good argument)

Sources for Case Studies:

- Online databases
- Academic articles
  - If the article itself does not pose a debatable question, pose one to the students based on the discussion in the article.
- Personal experience in the field

Summary of Assignment:

Assignment steps:

- Find appropriate case study
  - Use case study criteria. Create a summary for the issue presented in the case for students.
- Read Assignment
  - Present Students with assignment summary and assign it for them to read
- View 1 Argument
  - Assign students to decide on which view they find correct and defend it as assignment 1.
- In-class Discussion
  - Hold a discussion and have students discuss their thoughts on chosen solution and discuss argument with other students. Explore other observations and points-of-view for further analysis of the cases’ ethical issue.
- Opposite View Argument
  - Assign students to create logical and structured argument to defend the opposite view than the one they originally chose.

*Optional Final Step

- Feedback questions
  - Assign students to answer questions to give context to the assignment, including how useful they thought it was, what they think would have improved it, and how their understanding of the ethical issue and ethics in engineering has changed.
**Assignment Guidelines:**

In-class Discussion

○ Have students express their observations and arguments on the issue
○ Add any additional important arguments or points for both sides of the discussion

● Important suggestions:
  ■ If a majority of the class is defending one side of an argument, you must act as devil’s advocate by trying to get more students to switch arguments so that the debate is evenly distributed.
  ■ Make a list of the argument points for each side so that if any are missed, you can bring them up to students.
  ■ If the discussion is dying down, try proposing other factors to affect the debate and enhance participation
  ■ Try to be a mediator, allow students to debate directly with each other
  ■ As students make arguments, write them somewhere so that all students are able to visualize what different arguments are being made

Grading Criteria:

For grading purposes, the main components for a completed assignment:

1. Participation in class discussion
2. Logical arguments in assignment, no right or wrong argument
3. Both student arguments are fully supported
Analysis Method

Goal of assignment:

The goal of this assignment for the students is for them to successfully take a very complex case study, apply this method, and therefore break the issue down into all of its different factors and ethical issues. They should do so in such a manner that the issues can be analyzed, and solutions can be derived, evaluated, chosen, and discussed.

Analysis Method Example

The analysis method was also implemented as a trial run in the same biomechanics course. Students were given a case study and the analysis method to analyze the case study. The case study was about Johnson & Johnson launching a new metal hip implant in Europe because it was rejected by the FDA. However, there were high rates of failure in the implant and the company did not recall the device until after 3 years being on the market, despite warnings from doctors. The main ethical issue in this case study is the amount of regulation that medical devices must have because if more regulation is needed, it will take a lot more time for better medical devices to come onto the market and the cost of them would increase. After the assignment, the students discussed in class their ideas and a feedback survey on the assignment was given at the end.

An example of the expected student response can be seen in Appendix D. This example is based from the biomechanics trial run test of the Analysis Method strategy. In this case, the strategy was simplified, such that the students were required to identify all the ethical issues they could, and then pursue the remaining steps for just one of the issues.

Results

From the results for the analysis method, there was a 92% response rate from the students even though the assignment was relatively long. Many students wrote 2-3 pages for the assignment which was worth only one percent of the final grade. Also, 79% of the students said that they would definitely keep a copy of the analysis method and use it in the future. The students felt that the analysis method was helpful in organizing their ideas for a more complex case study that can contain multiple ethical issues.
Assignment Development and Instructions for Educator

Case Study Criteria:

- pick a case study with multiple issues
- Issues should have more than one solution and each have pros and cons

Sources for Case Studies:

- Online databases
- Academic articles
  - If the article itself does not pose a debatable question, pose one to the students based on the discussion in the article.
- Personal experience in the field

Summary of Assignment:

Assignment steps:

- Find appropriate case study
  - Use case study criteria. Create a summary or give students original article.
- Introduce Assignment
  - Present students with analysis method and case study (Refer to Appendix B for the Analysis Method Steps). Briefly go over the steps of the analysis method in class
- Analysis Method
  - Have students use the analysis method on the case study given
  - If time is an issue, students can be asked to use the method for only one issue
- In-class Discussion
  - Hold a discussion and have students discuss their thoughts on the issue they picked and their solution for that issue with arguments defending it.

*Optional Final Step

- Feedback questions
  - Assign students to answer questions to give context to the assignment, including how useful they thought it was, what they think would have improved it, and how their understanding of the ethical issue and ethics in engineering has changed.

Grading Criteria:

For grading purposes, the main components for a completed assignment:

1. Participation in-class discussion
2. Logical and complete arguments in assignment, no right or wrong argument
3. All six steps from the analysis method were used and student demonstrated use of all of its guidelines, as appropriate
Assignment Development Resources

Designing and Using Case Studies

A case study can be created from many different sources. Of course, there are case study databases; however, a case study can be from any situation or article that poses interesting issues for analysis. For example, the case study used for assignment one in class was derived from an experiment conducted in a laboratory. The report details the execution of a running test. In one test, an athlete sprained his ankle, and the data, after examination, showed the accepted model for ankle sprains may be incorrect. The researchers found that the ankle sprained differently than previously proposed. From this article, an ethical question was created in which your boss has asked you to continue the experiment with the goal of observing more ankle sprains for increased amounts of data for analysis. This statement introduced an ethical issue and directed the article from a purely academic article into an ethical case study. To see the full case study given to the class, refer to Appendix A.

Case studies can also be found in online databases such as Online Ethics Center or Ethics Education Library. These are just two of many resources found online where case studies on any subject can be found. For very specific classes, it can be difficult to find specific relevant case studies. An example to solve this problem comes from case study assignment 2. The basis for the case study was an article explaining the Deupy ASR metal hip implant. There were major problems with the implant and many ethical issues and debates are presented in this article. This article served as a base to form a case study assignment. With clear instructions to focus on ethical issues, many articles can be seen as case studies. One major key to picking a case study is it needs to be interesting to students, and it cannot be one sided. If the case is non-polarizing and most students choose one side of the argument, it will not be very effective for discussion. However, if the case allows for different views and debate, it will engage students more, and thus the education would be more effective.
Potential Ethical Topics

The following topics can be used in Biomedical Engineering classes as topics for the above stated methods.

Topics for Biomedical Engineering Applications:

- Compassionate care
  - Are drug companies obligated to provide compassionate care?
- FDA regulation
  - Over/Under Regulation?
- Human Testing
  - Knowledge for greater good vs. harm to individual
- Whistle blowing
  - Risk of being ostracized vs. doing the right thing
- Consent
  - How informed do patients need to be of side effects and hazards of experiments?
- Human Cloning
  - Organ Harvesting
- Gene Therapy
  - Effect of giving patients cancer
- Neuroethics
  - Should we allow the manipulation of the human brain and to what extent?
- Authorship
  - Who gets 1st authorship?
- Data Fabrication
  - Is it okay to omit data that will prevent funding even though you know that the data is wrong?
Works Cited


Biomechanics of supination ankle sprain: A case report of an accidental injury event in laboratory

Project manager: Daniel Fong
Supervisor(s): Kai-Ming Chan
Co-worker(s): Yosuke Shima, Tron Krosshaug, Patrick Yung, Y Hong
Project status: Published

Descriptions

Over the years, ankle kinematics has been studied during simulated sub-injury or close-to-injury situations, i.e., sudden simulated ankle spraining motion on inversion platforms (Myers et al., 2003). Since these tests did not induce real injury, they could only somewhat suggest the ankle kinematics during an ankle sprain injury. The most direct way is to investigate real injuries using biomechanical measuring techniques. However, it is obviously un-ethical to do experiments where test subjects are purposefully injured, but in rare cases accidents may occur during biomechanical testing (Barone et al., 1999; Zernicke et al., 1977). This study presented an accidental supination ankle sprain injury occurred in a laboratory under a high-speed video and plantar pressure capturing setting.

One male athlete (age = 23 years, height = 1.75m, body mass = 62.6kg) wore a pair of high-top basketball shoe and performed a series of cutting motion trials in a laboratory. The university ethics committee approved the study. The subject was instructed to run forward for six meters with maximum speed, before making a rapid left turn within the capture volume. In the fourth trial, the athlete accidentally sprained his right ankle with a supination mechanism.

The ankle motion was assessed using traditional marker-based motion analysis as well as a model-based image-matching technique for 3D reconstruction.

Results

The analysis showed that the injury situation deviated from the non-injury trials by a sudden inversion and internal rotation after 100-120 ms. Furthermore, the injury surprisingly occurred in
10-20° dorsiflexion. This finding is in contrast to previous hypotheses where a lateral ankle sprain occur in considerable plantar flexion. The prior hypotheses were, however, based solely on cadaver experiments and not real injury situations.


Based on the results, it is apparent that the model for ankle sprain needs to be improved, and the findings in the experiment could lead to an improved model. The current method appears to provide a novel method for studying ankle injuries when they occur in actual athletes. The athletes are paid to participate in the study, and the consent form signed by the athletes indicates that they understand the risks associated in participating in the original study and that the researchers cannot be held liable for injuries that occur. The researchers now know that there is a definite risk of injury, yet continued testing using the same methods could be provide more data to formulate an improved model of ankle sprain if the athletes happen to sprain their ankles during the trial. More human testing may also lead to improved designs to reduce ankle sprains.

1. Your boss has asked you to continue these tests to study sports physiology and also with the additional goal of better understanding ankle injuries. Would you agree to continue the testing in exactly the same way as planned in the original study? Write a paragraph on your opinion in the matter including pros and cons. You must make a decision either way - yes or no – and explain how you came to the decision.
B: Case Study Analysis Method

Analysis Method for Situations with Ethical Issues

This method for analyzing situations with ethical issues (a component of a problem that deals with morality, the concept of right or wrong, and/or social roles) is a form of engineering problem analysis and solving, applied to the concept of ethics.

Sections in blue are prompts for what the assignment requires from each step as a hand in.

Step 1: Identify Ethical Issues

Identify the problems of the situation and what ethical issues are present.

- Identify Ethical Issues:
  - Find these by searching for problems that involve moral concerns, have opinionated debate, and/or lack concrete answers
  - For any issues that are directly linked to other issues, and cannot be separated, treat them all as a single issue
- Identify additional parameters for each Issue:
  - Why this is an issue?
  - Who are the stakeholders involved?
  - Is there any missing or incorrect information?
- List these issues and their parameters

Step 2: Outline Possible Solutions

For each of the found ethical issues, find the possible solutions that can be followed in response.

- Find possible solutions by analyzing the problem and determining ways that it can be solved
  - What are the goals of the issue and how can they be achieved?
  - Check for solutions that have already been proposed
  - Research the issue’s related laws
- Describe these possible solutions

Step 3: Analyze each Solution

For each possible solution to each issue, analyze how it solves the issue and the problem.

- Analyze the pros and cons of how the solution solves the ethical issue
- Analyze how ethical the solution is:
  - Note what form of reasoning the option’s ethicality is based on:
    - reasoning methods:
      - societal moral law
      - concrete laws of society
• benefits and/or drawbacks for stakeholders
  • Write out analysis for each solution

Step 4: Construct Arguments for Solutions

For each possible solution to each issue, use analysis and reasoning to create arguments for why the selected solution should be used to solve the ethical issue and problem.

• Create argument and defense:
  ○ How it will solve the issue?
  ○ Why it is better than other options?
• Be sure to avoid your own bias affecting your argument or excluding possible solutions from analysis.
  • Write out all arguments

Step 5: Compare Solutions

For each issue, evaluate and weigh the effectiveness of each possible solution against each other.

• Compare the possible solution arguments to each other, in respect with:
  ○ The expected outcomes
  ○ The feasibility of implementation
  ○ The benefits and detriments to the stakeholders involved
  ○ Any factual assumptions, missing information, or logic errors
  • Write out all solution analysis

Step 6: Choose Solutions

For each issue, choose the solution with the strongest ethical reasoning and create a defense for your position.

• Use your answers from the previous steps to pick an optimal solution
• *Find areas of possible opposition in your argument and create an argument to counter them*
• Write out chosen solutions with reasons why they are the best option.
C: Example Student Output for Point/Counterpoint Strategy

Your boss has asked you to continue these tests to study sports physiology and also with the additional goal of better understanding ankle injuries. Would you agree to continue the testing in exactly the same way as planned in the original study? Write a paragraph on your opinion in the matter including pros and cons. You must make a decision either way-yes or no–and explain how you came to the decision.

Initial Argument

I would agree to continue working on the testing, after modifying the system so that it is a more transparent environment, both for the subjects and the conductors. With all of the medical innovations going on in the 21st century, animal testing has become inevitable. For one experiment, to tackle one topic, scientists conduct a wide variety of tests on live subjects such as rats, mice, worms, chicken and so on the list goes. Of course intellectually humans are much higher up in the “food chain” than these subjects but the main goal of all the experiments are mutual: to improve the quality of living (of course for humans). The system of the previous experiment could be modified so that the subjects who are signing up for it could fully know what the possible “risks” are. Instead of briefly giving a disclaimer and throwing the ball at them, they need to be fully aware of the consequences. Especially since the chosen subjects are athletes, whose lives depend on physical activity, it is crucial that they know exactly what they are signing up for. Only then, in my opinion, would it be acceptable to further proceed with the experiment.

Counter Argument

If my boss wanted me to continue using human test subjects for analyzing ankle sprains by having the subjects complete an exercise that puts them at risk for injury I would say no. Even though the exercise will usually not injure the subject there is a chance that they can sprain their ankle because the experiment requires sharp movements that puts a great deal of strain on the ankle. I believe that the possibility of injury to a volunteer, even though it will provide better results, is not ethical. It is bad lab practice to put the subject at risk. In a case where a human actually does endure an injury many problems can arise from a legal standpoint.

The subject is required to sign a consent form so that the researchers are not liable for what happens during the experiment. However, there is still always a possibility that the volunteer can become upset that they get injured and file some sort of complaint. This possibility is something that the research team and company does not need to deal with and can cause many complication for the company. If the subject decides to pursue legal action then we will be forced to hire a
lawyer and defend themselves in court. Despite the fact that we will probably win any legal battle the money and time wasted in the process is not worth the effort. Furthermore, the company and researchers will gain a bad reputation by putting human test subjects at risk. This reputation will likely make it more difficult to find volunteers for future experiments so the long term disadvantages do not outweigh the short term advantages that can be gained from the experiment.
D: Example Student Output For Analysis Method Strategy

**Identify Situational Parameters:**

The ethical issue in this paper is whether or not it is ethical of J&J to have put their hip joint replacement on the market with non-sufficient research to backup the approval of the device. This is an issue because several individuals reported permanent life problems after several years of the use of the device. The stakeholders are J&J Depuy. One assumption held is the accusation that the doctors involved with the approval of the device thought testing are companions with J&J and there is a belief that this held leverage over the doctors and the information was not completely accurate and not all information was shared.

**Issues:**

1. faulty approval
2. “off-label” use of the device
3. “similar-equivalence”
4. payments to surgeons that are involved in the design of a device
5. faulty marketing
6. surgeons tied with J&J were not reporting all findings after insertion of device
7. blaming the surgeon for the faulty device
8. neglecting the use against women

**Define Issues’ Options**

1. Option 1: Options that can be used to address the issues are evident. The first major problem should be the monitoring of the relationship between the surgeon and the company. The surgeon should not hold any stock or be getting any compensation for the use of the device. This causes ethical issues between the doctor and the patient. This will address issue 1,4 and 6.
2. Option 2: Another option to address 2,7,8 would be to have the surgeons have a hand in the approval of the device from a non-friendly responsibility and to have the surgeons trained by the engineers regarding the intent of use of the device.
3. Option 3: The final option would be to have a law that requires the company to provide insight on what may happen regarding any differences in a new device to help assist in the “similar equivalence” rule. This will exploit possible problems and address how to fix these possible problems. This will address issue 3.

**Analyze each Issues’ Options**

1. Option 1: The pros of this will allow the surgeons to have a non bias opinion regarding the actual reliability of the new device and the functionality of the new device. The con to this would be the slow process of new innovations to the market and the surgeons would be less likely to try a new product so there a monopoly may be formed where only one type of device is used due to the surgeons not really wanted to try a new device.
2. Option 2: The companies would no longer be able to blame the surgeons for the
failure of the device. The surgeons will also have a better idea on who the patients should be that are using the device. The con of this would be that the surgeons again may not want to go through the hassle of learning how to sue a new device.

3. This will exploit the possible problems that they new device may have based on the changes that are occurring in order to allow it to be brought to market. This will allow the engineers to be thinking about the possible failures, and to address those problems before the device is brought to market. This will also better insure the individuals using the device that the device is safe. The con to this would be the length of time required to bring a new device to market if each device had to go through this additional rigorous testing and analysis period.

**Construct Options’ Argument**

1. Option one would be a beneficial addition because it will remove all bias involved in the testing of the device. It will allow the testing to be seen though the eyes of the consumer in the sense of wanting the best for the consumer. There will be no bias and no exceptions in the regulation of all of the devices.

2. Option two would be beneficial because all implants will be implanted the way they were designed. Therefore, if they are used the way they should be in the types of individuals they should be used in, based on size or weight etc, this will remove any “user error” in the device. This will hold the companies accountable for making a device that they surgeons can easily use, but also correctly use every single time in a surgery.

3. The third option would be beneficial because this will allow all trouble shooting of the device to occur before the device can even reach FDA approval and testing. These problems will be more accurately accounted for and documented and therefore the FDA can hold the companies responsible to these problems and to prove that these problems will not actually occur during field use.

**Evaluate options’ arguments**

1. The best option out of the three would be the second option. This option will allow for the FDA to hold the companies accountable for the failures of the device and how they would be fail. This would make is so that even if the doctors have a relation with the companies, that the device will still have a less chance of failure. The next best option would be the first option. This will allow for no biases to be evident in the passing or failure of a device in the eyes of the FDA and the rest of the world. There would be no stake holders or anyone benefiting from whether or not the device is approved, therefore there would be no reason to lie about the testing results or hide any faulty information. The next best option would be the second option because this will allow the device to be used without doubt the way it is intended to be used; therefore there will be less issues with the device.
Choose Solutions

1. The option that I would choose to address this ethical dilemma would be option number one. By limiting the involvement of the testers in the stakes of the device then this will limit the faulty information being released regarding the device and all of the flaws will be highlighted and brought forward. If the surgeon or the testing individuals have a hand in the stakes of the device then they will be more likely to share faulty information and results or hide problems that may be occurring so that they will receive the compensation they were expecting. The fault of the second option would be the likelihood of the doctors to want to re-learn how to use a device that may have similar results in surgery than the old one that they may be currently using. This is how monopolies are formed in industry. The third option would be beneficial but there are already standards that cover similar material so it would not be a new option but instead just a re-finishing of a current process.