

Teaching Ethics in Engineering: A Proposal for Integrating Responsible Engineering Principles Into an Undergraduate Engineering Curriculum

RBE 595: Independent Study in Ethics

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1. Introduction

Ethics consists of guidelines that are integral to a functioning society. As laws cannot cover all situational outcomes, human societies instill values and ways of thinking through written and verbal language (**Ethics, tools, and the engineer, p276**). As such, ethics is tied to the life one lives and the decisions one makes.

Consequently, engineers, as those who design, make, and use new tools and create the structures used by societies, must have a strong ethical background so as to maintain order. In engineering, ethics is part of the knowledge, skills, and behaviors that students who have completed undergraduate-level education are expected to know and “be able to do” by the time of graduation (ABET accreditation). ABET, the Accreditation Board for Engineering and Technology, has three student outcomes that relate to ethics. These outcomes are stated as follows:

General Criterion 3. Student Outcomes.

The program must have documented student outcomes that prepare graduates to attain the program educational objectives. Student outcomes are [...]

(f) an understanding of professional and ethical responsibility

(g) an ability to communicate effectively

(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context

From an academic accreditation standpoint, ethics is incredibly important to the curriculum because ethics ties into the development of the responsible engineer, that is, an engineer who has awareness of character and carries responsibility for his or her actions. From a professional standpoint, ethics spans professional conduct, social responsibility, and good engineering design, which takes into account historical implications and environmental impact (**Schimmel**).

Now ABET is redefining these outcomes and has added a proposed change for consideration in the Fall 2016 conference where:

Criterion 3. Student Outcomes.

The program must have documented student outcomes. Attainment of these outcomes prepares graduates to enter the professional practice of engineering.

Student outcomes are [...]

4. An ability to communicate effectively with a range of audiences

5. An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgements, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.

6. An ability to recognize the ongoing need for additional knowledge and locate, evaluate, integrate, and apply this knowledge appropriately.

7. An ability to function effectively on teams that establish goals, plan tasks, meet deadlines, and analyze risk and uncertainty.

The modified outcomes have an increased emphasis as to how proficient undergraduates must be at utilizing ethics in their day-to-day lives. In the original criteria, notice that the student outcomes only require “an understanding of professional and ethical responsibility” as opposed to “an ability to apply ethical understanding” (Schimmel). ABET is making schools responsible for making students aware of how to make informed judgements and consider the impact of engineering solutions. The changed criteria means that educators are tasked with training students to recognize ethical and professional responsibilities in engineering situations and make informed judgements. Additionally the original criteria focused mostly on engineering impact, which relates to macroethics (ethics in society), whereas the newer criteria also includes emphasis on effective engineering practice, which relates to microethics (ethics as an individual) **(Schimmel) (Ethics for Beginners)**.

Project Objective

The purpose of this document is to evaluate current approaches to form a coherent method suitable for an undergraduate curriculum that integrates topics relevant to a young professional to capture a young engineer’s interest and form a useful toolkit that can be applied outside of the classroom.

2. Background

The purpose of this section is to create a more holistic foundation for understanding ethics. This section covers a brief history of where ethics comes from, what ethics is, the role of ethics in engineering, and how ethics has been taught to engineers. Ethics has a long history and its role in engineering should be seen in context.

Definition of Ethics

Ethics is “derived from the ancient Greek word “ethikos” meaning the study of morals; the ancient Greek root word is “ethos” meaning character or habit” (Steve Wakins ASEE). Morals relate to those beliefs on what is right or wrong; examples of an universal belief held by most people is that to steal, murder, lie, or physically harm someone is wrong (Professional Ethics and Economic Decisions, 7th ed, p 7). “Ethics are verbal guidelines that are used with the intention of modulating or controlling [voluntary] human behavior... to courses of conduct that normally promote human well-being or survival,” (Ethics, tools, and the engineer, p48). As such, ethics typically extends to define the principles of conduct governing an individual or a group.

When Ethics Is Commonly Taught

The tools used to determine right and wrong actions, and their corresponding consequences and the rationale behind the decisions of these actions, are taught starting at a relatively young age through the use of values. Values, or measures of worth, are preassigned to objects and actions encountered in life by the adults who raise us. These values are dependent on what the adult wants to encourage and promote (Ethics, tools, and the engineer, p56). Through punishment, reward, and observing “good role models” such as parents or teachers, children adopt and develop their own rules (ibid). Arguably what makes an action fair or just is reinforced by social norms and the pressures to “fit in” with one’s peers; this is a much larger factor than say, religious institutional beliefs, which were reinforced by a fear of the afterlife (paradise or damnation) (ibid).

The Role of Ethics in a Society

These rules and values taught to us at a young age through personal interactions forms the basis for societal and cultural norms. Arguably, the responsibility for one’s actions is what allows a society to function and not descend into chaos. Stewardship is defined as the activity or job of protecting and being responsible for something (Merriam Webster). In the case of most cultures, each adult citizen is a steward of the community and its beliefs. With this definition in mind, stewardship towards each other is generally well-ingrained.

What Ethics Combines

Ethics integrates a variety of personal qualities, skills, and processing tools necessary for both evaluating a given situation and interacting between individuals and within larger groups. From a personal perspective, ethics is a combination of character, perspective, creativity, empathy, conflict resolution, stewardship, and communication. These personal aspects are defined as:

- Character: The personal quality involving integrity and honesty and overall moral excellence (<http://www.dictionary.com/browse/integrity>)
- Perspective: The ability to see the relevant data for a given situation (<http://www.dictionary.com/browse/perspective?&o=100074&s=t>)
- Creativity: The ability to transcend traditional ideas, rules, and patterns to create meaningful new ideas and interpretations (<http://www.dictionary.com/browse/creativity?s=t>)
- Empathy: The psychological identification with the feelings, thoughts, or attitudes of another (<http://www.dictionary.com/browse/empathy?s=t>)
- Conflict Resolution: The ability to nullify or mitigate different viewpoints so as to avoid or resolve strife in a relationship
- Stewardship: The activity or job of protecting and being responsible or obligated to manage or care for something (<http://www.merriam-webster.com/dictionary/stewardship>)
- Communication: The act or process of using words, sounds, signs, or behaviors to express or exchange information, thoughts, feelings, or ideas to someone else (<http://www.merriam-webster.com/dictionary/communication>)

Some of the tools necessary for evaluating a given situation and interacting between individuals are formed when developing the personal qualities and skills described earlier. For instance, communication can be a tool (in addition to being a skill) when used in specific ways, such as in practicing negotiation tactics when reasoning with an individual. Additionally there are several frameworks as to how to view ethics, which also serve as “lenses” to provide different world perspectives and compartmentalize an ethical situation to make a situation more understandable or solvable. All of these methods and routines are used to develop a comprehensive understanding in managing thought processes and decisions made in day-to-day life.

Ethics, as applied to engineering

Engineers have a responsibility to use the resources at their disposal to the greatest advantage of the society who made those resources available (**Ethics, tools, and the engineer p 119**). Ethical problems for engineers come in two forms: the first is “process-based”-- when a conflict of interest arises while the engineer is doing work for whomever is paying for the work, while the second is “product-based”-- a result of the products of that engineered process causing some effect on the communities who are prepared to pay for them (**Ethics, tools, and the engineer p 120**). The process-based problems are similar to all other fields of science while product-based conflicts are generally unique to engineers (**ibid**). Some examples of process-based conflict are fabrication and falsification of data, plagiarism, data manipulation, and whistle-blowing (**Ethics, tools, and the engineer p120-132**). Some examples of product-based conflict include the creation of the nuclear industry, gunpowder, polymers, modern-day transportation systems, and gene therapy (**Ethics, tools, and the engineer p 132-142**).

In society, engineers are commonly viewed as the stewards of the community, particularly when it comes to infrastructure, such as the design, construction and operation of projects that involve public

safety. It is also probably not surprising that every professional society's code of engineering ethics states that holding the welfare and safety of the public is paramount in design considerations. Consequently, ethics is an integral part of one's approach to solving complex problems. Engineering ethics "calls for a level of performance in addition to moral purpose and intention" (**responsible engr by pritchard**). This is no different from other professions such as medicine or advertising, where individuals interface between society and the environment on a micro and macro scale.

Many types of rules guide an engineer's behavior. These rules range from laws to government regulations, employer policies, professional consensus, peer expectations, cultural norms, religious standards, and predicted consequences. In order to not get overwhelmed by these additional constraints, professional engineering societies take these rules and form them into international standards in the form of a code of ethics (**American Society for Engr Education- Teaching Engr Ethics by Steve Wakins**). These ethics resources are necessary as engineers encounter issues such as public safety, accessibility of information, and protection of intellectual property (**American Society for Engr Education- Teaching Engr Ethics by Steve Wakins**). However, these codes do not formally state (nor help) with an understanding of how to apply ethical principles (**responsible engr by pritchard**).

Teaching Ethics

Historically, the approaches to teaching ethics involve lengthy case studies that prevent students from investigating and questioning the assumptions given. Case studies are a useful tool in that in the process of analyzing and discussing a case, the studies help students learn that foresight is hard to develop, especially in a large complex system (**Ethics for First-Year STEM**). Case studies are difficult to defend because strict moral reasoning is hard to apply and most students rely on their own personal belief system to judge, causing mixed results (**ibid**). However, case studies provide hindsight one would not have had otherwise, and show the consequences (unintended or not) of the decisions made on a project (**ibid**). Many national agencies such as the National Association of Engineers (NAE) have since realized that only using case studies to teach ethics is not useful for most engineering students, simply because young engineers do not encounter catastrophic ethical issues as presented in the classroom until much later in their careers, if at all (**Engr Ethics Education: Aligning Practice and Outcomes**).

In general, experienced engineers consider engineering ethics important but engineering students do not (**NAE infusing ethics into the development of engineers**). Research has shown that if an individual feels like they have control over the situation, then they are more likely to behave ethically (**Engr Ethics Ed: Aligning Practice and Outcomes**). Perhaps students are not as interested because they do not feel that their actions can make a difference in most situational outcomes.

Relevance of ethics in an education

Ethics is relevant in an education because formal training helps to standardize the actions of the professionals in the field. In practicing and building ethical awareness, students can create a strong foundation. Unless you have some prior knowledge as to how to deal with ethical conflict or have some external validation of your boundaries and morals, the lack of ethical awareness will result in some sort

of minor infraction, if not a failure later on in your career. This could be in your team, your leadership, your company, or your industry.

It is important for young engineers to cultivate a collaborative process that provides insight and understanding into the causes and consequences of any new technology introduced into the world (**Rick Miller**). As the individuals who have an in-depth technical training, engineers are better equipped to predict and deal with the conflicts that may arise with the tools that are developed. There is an inherent responsibility all engineers have to ensuring beneficial outcomes for all.

Ultimately, decisions are made within a group of individuals that determine a situational outcome, and that group may include technical and non-technical individuals. However, given the state of most engineering curricula, most engineering students are not aware that sometimes the right engineering decisions involve negotiations with multiple non-technical stakeholders. As young engineers progress through their careers, cross-disciplinary and cross-cultural communication skills are key to being an ethical engineer.

Communication is an integral part to mitigating ethical conflicts because words form the foundation of any ethical teachings. Additionally, if an engineer cannot communicate what they accomplished or tried, then their findings will be relatively unknown at best. It is ironic that in a field that depends so heavily on teamwork and collaboration that many programs do not include cross-disciplinary team projects or an emphasis on good communication skills such as conflict resolution.

Summary

At its core, ethics is a set of words that communities ensure they conform to in order to ensure a better future. Engineers have a responsibility to ensure that the tools they maintain or create uphold these rules as well. Consequently, engineers must develop their own set of principles that can be used to evaluate a given situation, and must be given opportunities to practice and validate these principles.

3. Discussion of Findings and Approaches

This section provides a literature review about the current state of ethics education methods and techniques. The material provided in each subsection directly corresponds to the source noted in the subheading.

NAE Survey of Ethics Education Courses: Infusing Ethics into the Development of Engineers: Exemplary Education Activities and Programs—The current state of engineering ethics education in the US

<http://www.nap.edu/catalog/21889/infusing-ethics-into-the-development-of-engineers-exemplary-education-activities>

A wide variety of sources provided insight into the current teachings of engineering ethics. Class assignments showed that connecting younger students with experienced engineers who have experienced ethical dilemmas has an influential impact on how ethics plays an important role in engineering (**NAE infusing ethics into the development of engineers**). Professors asked students to interview professional engineers in their own network about ethical situations they have encountered (**ibid**). There is much difficulty in evaluating student performance on ethical decisions, however certain universities have proposed that students are more engaged when writing their own case studies (**ibid**). What is perhaps the most alarming of the traditional approach of catastrophic case studies is that the analysis of these cases causes engineering students to focus on negativity in engineering and leads those students to believe that the engineer is the sole decision maker for preventing major ethical situations, when in reality they are usually a member on an interdisciplinary team that makes these decisions together (**ibid**).

Out of 25 approaches presented, only two university approaches seemed to emphasize a broader view than catastrophic case studies: Cal Poly San Luis Obispo (SLO), and the Univ. of Illinois Urbana Champaign (UIUC). SLO takes a more historical approach—intertwining philosophical and mathematical history to illustrate how ethics in its current state in Western culture has come to be, and how ethics was influenced by the prevailing norms of morality through the ages (**ibid**). By contrast, UIUC developed a series of six 1-hour session course lectures covering relevant topics such as professional responsibility, conflict of interest, privacy of personal data, intellectual property, and accuracy of computational models (**ibid**). The scenarios covered in these six sessions were then evaluated according to the basic ethical values (honesty, fairness, trust, civility, respect, kindness, etc) and a couple of tests (Table 1) (**ibid**). Something the authors did not seem to touch on is that although these questions are good methods of evaluation, they all have different weighting in relation to each other depending on the situation. The tests for harm, reversibility, common practice, and legality all are useful in evaluating a solution, however the remaining tests of colleague, mirror, and publicity are very much based on potentially superficial or biased opinions, as they force a comparison that may be more personal and biased. The objectives presented by UIUC for their course were a tangible set of skills that could be evaluated (Table 2) (**ibid**). However, these objectives are tailored mostly to an approach of evaluating and preventing negative situations.

Evaluation tests	Description
Harm	Do the benefits outweigh the harms (short term and long term)?
Reversibility	Would this choice look good if I traded places with the other party?
Common Practice	What if everyone behaved this way?
Legality	Would this choice violate a law or a policy of my employer?
Colleague	What would a professional say?
Mirror	Would I feel proud of myself if I looked in the mirror?
Publicity	How would this choice look if it was on the front page of the newspaper?

Table 1. *These evaluation tests were proposed by a team of educators at UIUC for evaluating the potential of solutions to ethical dilemmas. (NAE infusing ethics into the development of engineers)*

Learning Objectives
Identify ethical problems and dilemmas
Recognize people affected and understand their perspectives
Identify comprehensive list of actions
Provide justified action to resolve the ethical problem/dilemma

Table 2. *These learning objectives were proposed by a team of educators at UIUC for structuring their course appropriately. (NAE infusing ethics into the development of engineers)*

Ethics as Design by Caroline Whitbeck – a comparison of ethics in engineering to engineering design principles

<http://www.jstor.org/stable/3527925>

Another proposed approach showed the parallels in solving engineering design problems and ethical problems as they are highly constrained. This analogy helps in naming the problem, which is quite influential in how the problem is solved. Rarely does a problem have a uniquely correct solution or response, and some possible responses are clearly unacceptable. Consequently, one solution is not necessarily better than the other, but poses different advantages. Both design and ethics approaches must achieve a desired performance/goal, conform to specifications, be consistent with pre-existing constraints, and by meeting those constraints, not induce severe unintended consequences (**Ethics as Design: Doing justice to moral problems**). Quite often when confronted with an ethical dilemma, there is a lack of clarity on how to evaluate the situation, generate alternatives or understand the solution space, devise a course of action, and predict what the consequences may be (**Ethics as Design: Doing Justice to Moral Problems**). Just as design thinking is highly situationally dependent and time constrained, ethical approaches also share these constraints, and so design thinking/ethical thinking is more of a framework as opposed to a series of set rules (**Ethics as Design**).

Responsible Engineering: The Importance of Character and Imagination by M.S. Pritchard-- How ethics is an intrinsic part of being an engineer and a member of society

<http://link.springer.com/article/10.1007%2Fs11948-001-0061-3#page-1>

Perhaps the most enlightening perspective is where ethics is more an extension of being a responsible engineer, as moral character and virtue influence one's approach, and one's approach influences the outcomes of a given engineering project. True character is shown through actions performed when no one is looking (**Responsible Engr**). Again, engineering ethics literature focuses on the negative consequences, and the codes of ethics do not usually provide help in interpreting the vague description of an engineer's responsibility to protect public safety, health, and welfare (**Responsible Engr**). Consequently, this results in a lack of understanding of the spectrum of ethical problems; that is, not all ethical dilemmas are negative in outcome or circumstance. Common characteristics for responsible exemplary engineers, such as integrity, honesty, courage, etc, are also those that are desirable for most other individuals and professions (**Responsible Engr**).

ASEE Teaching Engr Ethics by Steve E. Watkins—Another style of case studies

<https://www.asee.org/documents/zones/zone3/2015/Teaching-Engineering-Ethics.pdf>

By looking at engineering as a profession, Watkins conveyed a range of ethical issues in a given engineering area by introducing relevant codes of ethics from various professional engineering organizations and by providing case study examples. One of the more relevant examples was that of accepting job offers, which can be an ethical situation encountered early on in one's career. He poses the question of what if you get a better offer after you sign onto another company, and leads into a discussion about values. This seemed to be one of the more relevant examples to discuss as discussing job offers is fairly relatable—most students eventually have to (if they have not already) undertake the job-finding/hiring process. Not only do the students walk out with a clear example of how to apply ethical judgement, but they can also apply their ethical knowledge when it comes time to find a job by accepting an offer in an ethical manner.

Workshops for Integrating Ethics into Technical Courses (2006)—Focused more on how to run an engineering ethics course by Michael Davis

<https://www.uvu.edu/ethics/seac/Davis-IITs%20workshops%20for%20integrating%20ethics%20into%20technical%20courses.pdf>

Although the article focused on how to run a brand-new engineering ethics course more effectively, the author did cover some useful objectives that all course should have. The minimum objectives for teaching ethics should focus on ethical sensitivity, knowledge, and judgment. By raising ethical sensitivity, one increases a student's ability to identify ethical issues. Through enhancing ethical knowledge, such as familiarizing students with relevant codes of ethics, students become aware of potential resources that they can use. By improving ethical judgment, one improves a student's ability to make good choices for good reasons. These are all useful objectives to include in any new ethics course.

Ethics for first year STEM: A risk assessment based approach by Tobias Rossmann

<https://www.asee.org/public/conferences/56/papers/11730/view>

Risk assessment and cost benefit analysis methodology gave context to frame ethical problems that helped students develop other reasoning and judgment tools that were not as reliant on personal beliefs. The risk assessment process follows a series of broad questions about risks and benefits and the situation at hand, and then focuses on the decision makers, stakeholders, and existing constraints (Table 3). This process was used to evaluate various case studies introduced in the classroom, which covered mostly the engineering and cultural implications of recent and historical disasters, which included those created by nature, engineering, or conflict (terrorism). Writing prompts were also used to identify what students thought were the societal implications of these catastrophes, and their responses to posed scenarios, such as, "When working in a global marketplace, whose laws prevail? Those of the home country, or the country you're in?" (**Ethics for first year STEM**). An issue with some of these critiques is that the evaluators themselves (the students) have very little experience in those situations and may not be able to identify with the posed scenarios, or know where to start. Presumably the professor in this classroom study found that by practicing how to address these situations, the students were more comfortable in these fairly uncertain, ambiguous situations as well.

Question	Type
<ul style="list-style-type: none"> - Is the system under discussion worth the risks connected with its use? - What are the benefits? - Do they outweigh the existing laws and regulations (rules)? - What are the risks? - Is there any more information you need on decision makers/constraints/context/implementation? 	Preliminary
<ul style="list-style-type: none"> - Examine the fundamental technology and the needs met <ul style="list-style-type: none"> o What were the motives/conflicts of the decision makers and the stakeholders? o What were the constraints in which that technology was implemented (including political, societal contexts, and long-term effects)? 	Examine

Table 3. *The risk assessment approach as detailed by the paper included questions for holistic understanding as well as an examination of the technology and needs involved.*

Giving Voice to Values: An Alternate Approach for Viewing Ethics by Mary C. Gentile

Mary C Gentile is a Senior Research Scholar at Babson College who has undertaken numerous studies in better understanding and creating tools to teach business ethics. Many of the techniques she has posed are applicable, although not presented in a strict engineering sense. Giving Voice to Values is the result of decades of research, and is a program that has been conducted at over 480 organizations and business schools worldwide(<http://www.babson.edu/Academics/faculty/profiles/Pages/gentile-mary.aspx>). Her approach is that if you know what your values are, if you practice what your actions and responses are, then when confronted with a situation you will know how to respond in an ethical manner.

Book: <http://www.givingvoicetovaluesthebook.com/>

Curriculum Website: <http://www.babson.edu/Academics/teaching-research/gvv/Pages/home.aspx>

Although a course designed for classes in business ethics, Gentile focuses on post-decision-making, that is:

- o Not about deciding the right thing to do, but rather about how to get the right thing done
- o More about action than about analysis (otherwise you may not stop anything)
- o More about learning who we already are than about learning to become better or other than who we already are

Her process assumes you want to voice your values and act upon them in some way, and that it is also easier to act upon values if you practice how to respond to frequently encountered conflicts. The better you know yourself, the more prepared you can be to play to your strengths, as “The only real and ultimate control we have is over ourselves” (IBID). Additionally, morals emphasize right/wrong. It is

beneficial to look instead at values since they imply an inherent worth/quality of a thing/idea, are based more on “goodness.” Given that ethical conflicts come in all times, preparing for conflict mitigation by building skills and examining values can be beneficial at the time of the event. By reflecting and practicing control over our values, and ourselves, we can better prepare and control our reactions and possibly prevent a bad situation from becoming worse.

The process is as follows: self-assess, rationalize, and understand.

- Self assessment questions:
 - o Think about your professional and personal purpose. What impact do you want to have? Why are you working/studying/doing what you are doing?
 - o What is your personal risk profile? (Eg. What risks are you willing to take in your personal and professional life?)
 - o What are your personal communication style(s)/preference(s)?
 - o What is your loyalty profile?
 - o What is your self-image?
- Rationalization questions
 - o What is the action/decision that we believe is right?
 - o What are the main arguments against this course that we’re likely to encounter? What are the reasons and rationalizations we will need to address?
 - o What’s at stake for key parties, including those who disagree with us? What’s at stake for us?
 - o What are our most powerful and persuasive responses to the reasons and rationalizations we need to address? To whom should the argument be made? When, and in what context?
- Understanding personal biases, which include:
 - o obedience to authority
 - o social proof (“group think”)
 - o false consensus effect (tendency to believe others think as we do)
 - o over optimism (our optimism leads to irrational choices)
 - o self serving bias (tendency to look for information that confirms pre-existing views)
 - o framing (how we pose a question/scenario)
 - o process (tendency to take certain actions you would have found objectionable had you not been eased into them through a series of smaller, less extreme choices)
 - o cognitive dissonance (urge to avoid information/conclusions that make us uncomfortable)
 - o sunk costs and loss aversion (tendency to continue with less than optimal course of action because one is reluctant to accept previous choices or investments were wrong/wasted or accept loss).

Although not taught in an engineering setting, Gentile brings up a unique perspective as to how to build an ethical foundation. By assessing, rationalizing, and understanding personal biases, Gentile provides a method for self-reflection and self-correction of our own values.

ABET 2000- Can Engineering Faculty Teach Ethics? –Keith Schimmel (2000)

<https://www.calvin.edu/academic/engineering/ces/ceec/1999/schimmel.htm>

Schimmel presents a series of thoughts and opinions as to whether engineering professors are qualified or not to help mold a student’s ethical compass. He also covers core objectives that seem reasonable to include in an ethics course (Table 4). A useful technique he discussed was having students write analytical essays on ethical situations. “Probably the most effective way to demonstrate most of the desired outcomes is through student portfolios that contain samples of student essays analyzing ethical issues with which a practicing engineer may be faced. These types of essays provide opportunities to demonstrate how a student applies knowledge of different ethical theories to make a decision on what the right thing to do is in a given engineering decision dilemma.”

Sample Outcomes (as suggested by Schimmel)
1. Ability to offer and defend a definition of engineering ethics
2. Ability to recall the essential elements of a professional engineering society code of conduct
3. Ability to list and explain multiple reasons for being ethical in the practice of engineering
4. Ability to identify and critically analyze common ethical dilemmas in the practice of engineering, including possible consequences
5. Ability to analyze ethical arguments to discover which argument one has the best reasons to believe and act upon
6. Ability to speak and write in a way that is logical, complete, consistent, and clear, and that can recognize potential objections to one’s position
7. Ability to recognize the historical importance to our society of previous ethical decisions made in relation to engineering and technology
8. Ability to recognize actions that expose oneself to legal liability
9. Ability to use basic risk assessment techniques in the engineering decision-making process
10. Ability to recognize the regional and global consequences of engineering decisions

Table 4: Sample outcomes for an ethics engineering class offer concrete ways to measurably define tangible skills and analytical skills for an engineer.

Summary

The literature shows that many have researched how to teach ethics to engineers. Ultimately, no one approach is necessarily the “best” one to follow. A recommended solution is to combine the variety of the methods presented to develop the well-rounded engineer.

4. Teaching Recommendations

A different approach to teaching ethics in engineering is necessary in order to make ethics relevant to the students taking it. As opposed to the case study approach, it has been shown through numerous studies (see **Ethics for First-Year STEM** for example) that it is more relevant to show and help students develop tools in analyzing their own approach, assumptions, and personal beliefs within the framework of ethics education. Pritchard's view resonates as engineering educators should be focused on teaching ethics as an approach to the holistic thinking process of an exemplary engineer in all situations.

Proposed outcomes

1. Ability to follow a series of logical steps to evaluate a situation and come up with a plausible solution
2. Ability to analyze ethical arguments to discover which argument one has the best reasons to believe and act upon
3. Ability to recognize the historical significance and situation in which previous decisions have been made
4. Ability to evaluate a situation via risk assessment techniques
5. Ability to reason and determine one's personal biases and values to better address an ethical situation
6. Ability to recognize consequences of an engineering decision
7. Ability to see how ethics is integral to engineering and being a responsible citizen of society

Proposed exercises to teach ethics (Details in Appendix A):

Notes: (which can take as much or as little time as the instructor has)

- Building Empathy: How can you get to know and understand someone else's intentions, motivations, and opinions without immediately jumping to conclusions about right or wrong?
- Understanding and Preventing Bias: What are some personal and cultural biases and how might they factor into your own decision-making processes?
- Responsible Engineering: What does it mean to be a "responsible" engineer and why do we use that term?
- Write-your-own case study: Have students go through the process such that they can discuss their own cases with their peers in a neutral forum.

Proposed objectives:

- Students should learn what resources are available to them and become familiar with how to find and use them.
- Students should take the time to reflect on their own personality and perspective in order to determine what they may (or may not) want to change.

- Students should be able to identify ethical situations and come up with promising solutions to these situations, as it is better to come to a superior with a solution than with just a complaint.
- Students should be comfortable with the tools they have developed throughout the course to approach ethical situations

5. Summary

Engineers face ethical challenges as a part of their lives and their profession. Building a concrete set of skills, personal introspective tools, and ways to “condition” oneself for a given situation are vital to being a responsible individual. All approaches detailed above had key takeaways that are useful for all engineers:

- Engineers do not work alone, nor are they the sole decision makers, so negative case studies that highlight the engineer’s ethical dilemma should be evaluated more critically.
- Framing [a](#) problem is [the](#) key to naming and analyzing [a](#) situation.
- Not all [design](#) solutions are acceptable, and not all solutions can fit multiple problems.
- “Ethical system” is exterior to all systems, not exclusive, but one of many important systems in a complex system.
- Ethics is more than just situation management; it is a way of practicing engineering—a way of “being.”
- Applying ethics in engineering involves identifying ethical situations, knowing what ethical resources are out there, observing your own approach to ethical dilemmas, and resolving an issue in an ethical way.

References

<http://www.merriam-webster.com/dictionary/ethic>

Field Code Changed

L. Blank and A. Tarquin, *Engineering Economy*. McGraw-Hill Education, 2011.

R. Spier, *Ethics, tools, and the engineer*. CRC Press, 2001.

M. C. Gentile, *Giving Voice to Values: How to Speak Your Mind When You Know What's Right*. Yale University Press, 2010.

"Ethics for First-year STEM: A Risk Assessment Based Approach: American Society for Engineering Education." [Online]. Available: <https://www.asee.org/public/conferences/56/papers/11730/view>. [Accessed: 12-Jul-2016]

"Definition of STEWARDSHIP." [Online]. Available: <http://www.merriam-webster.com/dictionary/stewardship>. [Accessed: 11-Jul-2016]

"ABET 2000 -- Can Engineering Faculty Teach Ethics?" [Online]. Available: <https://www.calvin.edu/academic/engineering/ces/ceec/1999/schimmel.htm>. [Accessed: 11-Jul-2016]

"Criteria for Accrediting Engineering Programs, 2016 – 2017 | ABET." [Online]. Available: <http://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2016-2017/>. [Accessed: 11-Jul-2016]

K. M. Passino, "Educating the humanitarian engineer," *Sci. Eng. Ethics*, vol. 15, no. 4, pp. 577–600, Dec. 2009.

M. Davis, "IIT'S WORKSHOPS FOR INTEGRATING ETHICS INTO TECHNICAL COURSES: SOME LESSONS LEARNED 1," *Teaching Ethics*, vol. 6, no. 2, Spring 2006 [Online]. Available: <https://www.uvu.edu/ethics/seac/Davis-IITs%20workshops%20for%20integrating%20ethics%20into%20technical%20courses.pdf>

State of Texas and Texas Tech University, "Nine Basic Steps to Personal Ethical Decision Making | Resources and Guidance | Educational Products and Services | Murdough Center | TTU." [Online]. Available: <http://www.depts.ttu.edu/murdoughcenter/products/resources/steps-to-personal-ethical-decision-making.php>. [Accessed: 24-Jun-2016]

S. E. Watkins, "Teaching Engineering Ethics," presented at the 2015 ASEE Zone III Conference [Online]. Available: <https://www.asee.org/documents/zones/zone3/2015/Teaching-Engineering-Ethics.pdf>

T. Rossmann, "Ethics for First-year STEM: A Risk Assessment Based Approach: American Society for Engineering Education," presented at the 2015 ASEE Annual Conference and Exposition [Online]. Available: <https://www.asee.org/public/conferences/56/papers/11730/view>. [Accessed: 24-Jun-2016]

R. Miller, "The Talent Abyss: The Need for Radical Change in STEM Education - High Tech MATTERS," *High Tech MATTERS*, 11-Apr-2016. [Online]. Available: <http://blog.mhtc.org/talent-abyss-need-radical-change-stem-education/>. [Accessed: 15-May-2016]

F. F. Benya, C. H. Fletcher, and R. D. Hollander, Eds., *Practical Guidance on Science and Engineering Ethics Education for Instructors and Administrators*. National Academies Press, 2013.

M. J. Frazer and A. Kornhauser, *Ethics and Social Responsibility in Science Education: Science and Technology Education and Future Human Needs*. Elsevier, 2014.

M. Resnick, "Ethics and Morals and Olin, oh my! | Frankly Speaking," *Frankly Speaking*, 01-Mar-2016. [Online]. Available: <http://franklyspeakingnews.com/2016/03/ethics-and-morals-and-olin-oh-my/>. [Accessed: 02-May-2016]

M. S. Pritchard, "Responsible Engineering: The Importance of Character and Imagination," *Sci. Eng. Ethics*, vol. 7, no. 3, pp. 391–402, 2001.

C. Whitbeck, "Ethics as Design: Doing Justice to Moral Problems," *Hastings Cent. Rep.*, vol. 26, no. 3, pp. 9–16, 1996.

D. Bairaktarova and A. Woodcock, "Engineering Ethics Education: Aligning Practice and Outcomes," *IEEE Commun. Mag.*, vol. 53, no. 11, pp. 18–22, 2015.

C. E. Harris Jr., M. S. Pritchard, M. J. Rabins, R. James, and E. Englehardt, *Engineering Ethics: Concepts and Cases*. Cengage Learning, 2013.

Appendix A: Proposed Exercises to Teach Ethics

Increasing Empathy

Background: Engineers work in teams for their whole careers. Most teams through an engineer's undergraduate curriculum consist of other engineers; however in most companies, engineers interact with many more individuals than just engineers. On the whole it is important to instill a sense of empathy within a highly rational person (as are most engineers) to be able to perceive, mitigate, or prevent conflict.

Objectives:

1. For the student to identify the motivations, concerns, and trace the actions of the other individual(s) involved.
2. For the student to identify their own ability to step into other's shoes.

Example Exercise:

Prior to class: Have your students reflect on a situation they had recently concerning a team/personal conflict.

- Did it result from word choice?
- What was/were the various perspective(s)?
- What happened? What could you have done differently?
- How might you be able to approach someone who does not share your viewpoint?

In class: Have a discussion about some of the conflicts they identified while writing the essay.

Follow-up: Have the students write a reflection. What was the change, and what was the insight in their way of thinking?

Understanding and Preventing Bias (to the best of one's ability)

Background: Bias is present everywhere. It is an inevitable part of the sources of information we use, from the conversations we seek to the news feeds we read. Influenced by where we grew up, and what culture we grew up in, it is highly variable from individual to individual. In evaluating a given situation, it is important to develop a working “bad science” (BS) detector. But at the same time it is important to know what to and what not to question, or which sources are generally trusted.

Example Exercise:

Pre-class:

- Find an example of heavily biased news and try to find and verify the points it presents. Are they fact, or hype?
- Read through the engineering code of ethics. Is the article ethical? When might the code of ethics not be applicable? When should it be used? Are there times when engineers are more ethical and less ethical? What are some of the underlying factors or biases?

In class:

A. Discussion about where to find sources/references when conducting a comprehensive investigation

- What are the differences between popular news sources and not?
- How might a given news company's source of funding influence their bias?
- Who might you consult if you cannot find an unbiased source? (Hint: Research Librarian?)
- How might what you find influence your behavior towards an individual/organization who shares what you consider to be a conflicting view?

B. Discussion about personal beliefs, underlying assumptions, and biases

- What are some cultural influences you grew up with?
- What were some beliefs you were taught as a young child? Did these conflict with those of your peers? If so, how?
- What are some assumptions you make when you see an unkempt lawn? What are some assumptions you make when you see a beat-up car in a nice neighborhood? What are some assumptions you make when you interact with someone (particularly if they aren't an engineer)?
- What are some personal biases? What makes you feel comfortable? Are you ok with stepping out of that comfort zone? Would you feel more comfortable doing engineering work living in a tent in a third-world country? Or would you feel more comfortable being an engineer with a 9-5 job at a standard firm?

C. Discussion about the code of ethics and how it may or may not apply

- What is the code of ethics there for? Why do we care about it? What purpose does it serve?
- Does it apply to all aspects of an engineering career? Is it applicable outside of engineering?
- What values does the code of engineering imply and cover?
- Is the code biased? Or is it fair? What would you add to it?

Follow Up:

What did you learn from this module? What was the change? What was the insight gained? How might you apply what you learned to situations in the future? What changes can you make now?

Responsible Engineering: What does it mean to be a responsible engineer?

Background:

Engineering, as a profession, comes with traditions and responsibilities. As a steward of the community, engineers are trusted to guard and design structures, both in the virtual and physical realms. With the trust of the general public comes great responsibility. However, an ethical situation is not necessarily

Exercise:

Pre Class:

Required Reading: M. S. Pritchard, "Responsible Engineering: The Importance of Character and Imagination," *Sci. Eng. Ethics*, vol. 7, no. 3, pp. 391–402, 2001.

- What is Pritchard's premise for the argument he makes?
- Do you agree with the perspective of being a responsible engineer? Is this something you had considered prior to reading this paper?
- (Optional) Ask a mentor if they feel that they are responsible to society in some way. Did that stem from the skills they formed/training they might have undergone? Was there a specific experience that they had that was very helpful in the formative years? (Or something else?) What helped? What didn't?

In Class:

- A. Discussion about being a responsible engineer and being open-minded enough to solve the problem as a whole (which may involve more than just engineering)
 - a. What does it mean to be a responsible engineer? What does it mean to be open-minded? How can you solve "problems as a whole"?
 - b. What resources are important to have? Are relationships with other colleagues an example of resources to tap into? How might your network play into helping you (or harming you) when solving a given issue? How do you ensure you're "owning" your opinion and taking in others' perspectives?
- B. Discussion about finding out what your options are to resolving a situation (generally, under stress, individuals do not tend to survey the breadth of possibilities)
 - a. How much planning is necessary? How much is too much? When is it useful?
 - b. What resources are available to understand what your options are?
 - c. Are the rules that define those options always immutable?
- C. [Discussions of the concept of ethics as a system bounding all engineering design \(when thinking in terms of systems\)](#)
 - a. How is ethics a system bounding all engineering design?
 - b. Why is this a useful frame of reference for an engineer to have?

Case studies: Making Them Relatable

Background: Creation, swapping, and discussion of student-created examples of ethical situations they have encountered. This helps to identify when they have already used some form of ethical reasoning.

Exercise:

In class:

Discuss the following scenarios (based on [the author's personal](#) experiences):

- Your professor offers you an interesting summer project working on building an autonomous system for a local company. When you meet the owners, you realize that this solution your team is creating will replace the current system that will be out of service in 5 years since Everest, a large company, has acquired the supplier of the autonomous system. No student is supposed to work on a mission critical project (if the idea flops, the company dies), but your professor insists that it is not a mission critical project because the company has five years to execute. The project will roll into the senior capstone class in the fall. Do you have a discussion with the lead capstone professor, even though doing so may have negative repercussions on your relationship with your professor?
- At a team meeting, your teammates agree to stick to certain deadlines and have tasks completed. There is a virtual work-in-progress board to keep track of all the tasks. However, no one fills out the board, and three of your teammates (who are not from the US) do not stick to the deadlines or tasks assigned at all. They instead show up at your next meeting with an entirely different set of things to show than what was proposed. What do you do?
- An intern is working on their personal project at work, which their mentor, who is the head of the lab, is fine with. You also see them take parts from the stockroom, which you know are not frequently used and must be ordered in large quantities. Do you let them take it?
- Sitting in a lecture, you notice that the rest of your 60+ classmates are falling asleep, browsing Facebook, or doing work for another class. You realize that the assignments and the lectures are not very pertinent to your field, but it's a required class for the program. What do you do?
- On a team project, your team grade was a B because the team report failed to include a specified subsection. However, your teammates think that the project was graded unfairly as there was a paragraph describing what would have been in that subsection, but the team did not create the requested diagram and analysis. What do you do?
- You realize the product you are developing depends on a source of material that has harmful environmental consequences and is hurting the local economy. What do you do?
- Read this article about how electronics are "Recycled."
(<http://www.smithsonianmag.com/science-nature/burning-truth-behind-e-waste-dump-africa-180957597/?no-ist>) Is it ethical to buy a consumer electronic device? What could be improved or changed? How would you go about putting that change into action?
- Read the following article about eating meat.
(http://www.alternet.org/story/136449/consumption%2C_not_population_is_our_main_environmental_threat) Is it ethical to continue eating meat at the quantities we do? What are some potential solutions?

Follow Up:

- (optional): if extending to two class periods, this would be an excellent time to have the students write their own case studies based off those discussed in class.
- What did you learn from this module? What was the change? What was the insight gained? How might you apply what you learned to situations in the future? What was useful for you? What wasn't?