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Board 86: Teaching Ethics in an Electrical Engineering Program

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Work in Progress: Integrating Ethics into the Electrical Engineering Program

Abstract

The Accreditation Board for Engineering and Technology (ABET) mandates that engineering students demonstrate the capacity to recognize ethical and professional responsibilities in engineering contexts and make informed judgments, considering the global, economic, environmental, and societal implications of their engineering solutions. Unfortunately, there is a history of tragedies and disasters caused by unethical engineering practices, underscoring the crucial need for students to be well-versed in these cases and prepared to make ethical decisions in their future workplaces.

Integrating ethics into the electrical engineering curriculum poses distinct challenges. Within engineering programs, ethical considerations often vie for focus alongside technical aspects, potentially resulting in inadequate exposure and emphasis on ethical dimensions. Consequently, students may possess limited awareness and comprehension of ethical matters.

Few approaches exist for integrating engineering ethics into the curriculum. These range from standalone courses specifically dedicated to ethics, integration within philosophy coursework, to open discussions within capstone design classes, and modules infused into technical courses. Each approach carries its unique set of benefits and drawbacks. Regarding content, researching into engineering ethics entails an examination of ethical case studies. However, grasping the theoretical foundations of ethics is crucial for comprehending diverse ethical perspectives.

In the Department of Electrical and Computer Engineering at the University of Wisconsin-Platteville, we have developed two comprehensive ethics modules—an introductory and an advanced module—that seamlessly integrate into our curriculum. These modules are strategically incorporated into two critical phases of the academic journey: the freshman introductory course, and the senior level capstone design course.

The freshman module introduces students to straightforward cases, enabling them to understand the process of making ethical judgments. Assessment at this level includes a series of multiple-choice questions, ensuring active engagement with and comprehension of the ethical challenges in electrical engineering.

In the senior-level modules, students explore the theoretical aspects of ethics alongside more complex case studies. Each module comprises a mix of videos, textual content, and assessment quizzes. This report provides an overview of the modules content, implementation procedures, and assessment methods.

Introduction

In contemporary engineering, a comprehensive skill set goes beyond technical expertise to encompass social awareness, understanding of human dynamics, and navigation of complex issues. This expanded skill set is crucial because engineering endeavors frequently intersect with broader societal and environmental contexts, demanding that engineers weigh these considerations in their decision-making and solution design processes. Consequently, numerous engineering programs have evolved to provide a more inclusive education, integrating coursework in domains like ethics, communication, leadership, and project management. This approach equips graduates with a broader outlook, enabling them to appreciate the societal and human dimensions of their work [1,2,3].

ABET also mandates ethics education as a crucial component of engineering programs. It stipulates that engineering curricula must incorporate instruction in ethics, offering students opportunities to explore and apply ethical principles and values [4]. This requirement aims to equip future engineers with the necessary knowledge and skills to navigate ethical dilemmas and conduct themselves responsibly within their professional spheres. ABET's emphasis on ethics underscores its significance in engineering and highlights the imperative to cultivate ethical decision-making and responsible conduct among future engineers.

The recommended content for ethics instruction encompasses various elements such as professional engineering ethical codes, theoretical reasoning, moral theories, humanist readings, service learning, and case studies [5,6]. Evaluating the advantages and disadvantages of each content option [7,8] indicates that combining theoretical reasoning with case studies and service learning would enhance the effectiveness of engineering ethics instruction. Nevertheless, the use of case studies remains a prevalent method for teaching engineering ethics.

Case studies serve as a prevalent pedagogical method in ethics education, utilized across disciplines for engineers and non-engineers alike. While this approach offers distinct advantages, it also comes with limitations. One advantage is the ease with which case studies facilitate discussions on ethical dilemmas. However, a significant drawback lies in their often-succinct presentation, which omits crucial details. As a result, some educators contend that such cases may lack realism, thereby inadequately preparing students for the intricate ethical challenges they will encounter in real-world contexts. These cases are sometimes labeled as "thin examples" due to their limited depth of detail [9].

Few approaches exist for integrating ethics content into engineering curricula. These methods encompass standalone ethics courses within engineering departments, standalone ethics courses offered by engineering programs [10], ethics modules embedded in engineering technical courses [11], the infusion of ethics content throughout all technical courses, and various combinations of these strategies. Emphasizing ethics across the curriculum underscores the recognition that ethical and societal considerations are fundamental components of engineering education [6.8]. Clancy et al reported that they integrated an ethics laboratory into a basic course in electronic circuit [11].

We have created and incorporated two ethics modules into our curriculum: one introductory and one advanced. The introductory module is tailored for freshmen, while the advanced module is geared towards senior students. Below, we outline the objectives and contents of each module.

Ethics in electrical engineering curriculum

Prior to 2021, students enrolled in the electrical engineering program at the University of Wisconsin-Platteville were required to take a philosophy course offered by the humanities department to gain exposure to ethics. However, the impact of this course was minimal as it only partially covered general ethics concepts. Furthermore, due to constraints related to student course credits and available resources, the department faced challenges in incorporating a standalone ethics course into the curriculum.

As a solution, the department opted to integrate ethics education through online modules into two technical courses. These modules serve distinct purposes and are tailored to different student populations. The first module, designed for freshman students, provides introductory-level content on ethics. In contrast, the second module, targeted at senior students enrolled in the capstone design course, offers more comprehensive coverage of ethics topics.

Introductory ethics module

Similar to work reported by Clancy et al [11], we have opted to integrate an ethics introductory module into the Electrical Engineering Projects and Tools course. This one-credit laboratory course is typically taken by electrical engineering students in their first semester. The course aims to introduce students to various aspects of electrical engineering, including laboratory equipment and basic electrical circuits, through fifteen lab sessions held for over two hours each week. The introductory module consists of two videos, totaling 60 minutes, which students are required to watch in their own time. After viewing each video, students take a quiz to assess their understanding of the material. The module focuses on highlighting famous engineering disasters resulting from unethical decisions, with the aim of stimulating students' ethical imagination and enhancing their ability to recognize ethical issues.

We have deliberately selected simple cases that enable students to easily identify unethical decisions and actions. This approach aims to lay a strong foundation for further exploration of ethics in the field of electrical engineering.

The following cases were used in this module.

- The Space Shuttle Challenger Disaster.
- The Bhopal Disaster.
- The Deepwater Horizon Oil Spill.
- The Flint Water Crisis.
- The Toyota Acceleration Controversy.
- The Fukushima Daiichi Nuclear Disaster.
- The West Virginia Chemical Spill.
- The Grenfell Tower Fire.

Although unethical actions in these cases are simply recognizable, they highlight the importance of ethical considerations in engineering, and the need for engineers to prioritize safety, transparency, and accountability in their work.

Advanced ethics module

The advanced ethics module has been integrated into our capstone design course. The objective and outcomes of this module include:

1. Help students analyze key ethical concepts and principles.
2. Help students deal with ambiguity.
3. Increase student knowledge of relevant standards.
4. Improve ethical judgment.
5. Increase ethical willpower.

Advanced ethical principles refer to more complex and distinction approaches to ethical decision- making, beyond basic moral principles and rules. They are designed to help students navigate complex ethical dilemmas and make ethical decisions in a nuanced and thoughtful manner.

Some advanced ethical principles covered in this module include:

- **Utilitarianism:** The idea that an ethical decision should result in the greatest good for the greatest number of people. Examples covered using this methodology:

  Bridge Construction: In the design and construction of bridges, engineers often face decisions about safety measures and materials that can affect the overall cost and lifespan of the structure. Utilitarianism would argue for choosing options that maximize the greatest good for the greatest number of people, balancing factors like cost, safety, and longevity to ensure the bridge serves its purpose effectively while minimizing risks to public safety.

  Environmental Engineering: When designing and implementing environmental projects such as wastewater treatment plants or renewable energy facilities, engineers must consider the impact on ecosystems, communities, and future generations. Utilitarianism would advocate for solutions that produce the greatest overall benefit to society, including improvements in public health, environmental quality, and resource sustainability, even if they involve higher upfront costs or regulatory hurdles.

  Medical Device Design: Engineers involved in designing medical devices, such as pacemakers or prosthetic limbs, must weigh considerations of safety, effectiveness, and accessibility for patients. Utilitarianism would prioritize devices that provide the most significant improvements in quality of life and healthcare outcomes for the greatest number of people, even if they require additional research and development costs or regulatory approvals.

Transportation Infrastructure: Planning and designing transportation systems, including roads, railways, and airports, involve trade-offs between efficiency, safety, and environmental impact. Utilitarianism would advocate for investments in infrastructure projects that enhance mobility, connectivity, and economic growth while minimizing congestion, accidents, and environmental degradation, thereby maximizing overall societal welfare.

Energy Policy: Engineers and policymakers face ethical dilemmas in developing energy policies that balance competing interests, such as economic growth, energy security, and environmental sustainability. Utilitarianism would support policies that prioritize the transition to renewable energy sources, energy efficiency measures, and emissions reductions, as these initiatives offer long-term benefits in terms of public health, climate stability, and resource conservation for present and future generations.

These examples illustrate how utilitarianism, as an ethical framework, prioritizes actions that produce the greatest overall happiness or utility for the greatest number of people.

➢ **Deontology:** The idea that some actions are inherently right or wrong, regardless of their consequences. Examples covered using this methodology:

Whistleblowing on Unsafe Working Conditions: An engineer working in a manufacturing facility discovers that the company is cutting corners on safety protocols to meet production deadlines. Despite pressure from management to remain silent, the engineer decides to blow the whistle and report the unsafe working conditions to regulatory authorities, adhering to the deontological principle of duty to protect the safety and well-being of others.

Refusal to Work on Unethical Projects: An engineer is asked to develop a surveillance system that infringes on individuals' privacy rights. Despite the potential financial incentives, the engineer refuses to work on the project, citing ethical concerns and the deontological principle of respecting human dignity and rights.

Ensuring Product Safety Despite Cost Constraints: A design engineer is under pressure to reduce costs by using lower-quality materials in a consumer product. However, the engineer insists on maintaining high safety standards and refuses to compromise on product integrity, adhering to the deontological principle of duty to prioritize the well-being of end-users.

Reporting Academic Misconduct: A student working on a group engineering project discovers that a team member has plagiarized portions of their work. Despite the temptation to ignore misconduct to avoid conflict, the student reports plagiarism to the instructor, upholding the deontological principle of honesty and integrity in academic pursuits.

Environmental Protection in Engineering Design: An engineering firm is tasked with designing a new industrial facility in an environmentally sensitive area. Despite the potential profitability of the project, the firm insists on implementing sustainable design practices and minimizing environmental impact, aligning with the deontological principle of duty to preserve and protect the environment for future generations.

These examples illustrate how deontological ethics prioritize adherence to moral rules and duties, regardless of the consequences or outcomes.

- **Virtue ethics:** The idea that moral character and virtuous behavior are more important than following strict rules or principles. Examples covered using this methodology:

The Space Shuttle Challenger Disaster (1986): Engineers at NASA faced ethical dilemmas regarding safety concerns raised by engineers about the O-ring seals in the solid rocket boosters. The decision-making process leading up to the Challenger disaster raises questions about the virtues of honesty, courage, and responsibility.

The Volkswagen Emissions Scandal (2015): Engineers at Volkswagen intentionally manipulated emissions tests for diesel vehicles to meet regulatory standards. This case raises issues related to honesty, integrity, and accountability in engineering practices.

The Ford Pinto Fuel Tank Controversy (1970s): Engineers at Ford Motor Company were aware of safety concerns related to the design of the Pinto's fuel tank but chose not to address them due to cost considerations. This case highlights questions about the virtues of care, integrity, and social responsibility.

The Deepwater Horizon Oil Spill (2010): Engineers involved in the design and operation of the Deepwater Horizon drilling rig faced ethical dilemmas related to risk management, safety protocols, and environmental stewardship. Virtues such as prudence, accountability, and environmental awareness come into play in this case.

The Boeing 737 MAX Crashes (2018-2019): Engineers at Boeing faced ethical challenges related to the development and implementation of the Maneuvering Characteristics Augmentation System (MCAS), which contributed to two fatal crashes. This case raises questions about the virtues of competence, transparency, and accountability in engineering practices.

These examples illustrate how virtue ethics focuses on cultivating virtuous character traits, such as honesty, compassion, courage, fairness, and respect, to guide ethical decision-making in various contexts.

- ➢ **Care ethics:** The idea that ethical decisions should prioritize the well-being and care of others, especially those who are vulnerable or marginalized.
  Therac-25 Radiation Overdoses: The Therac-25 was a medical linear accelerator used for radiation therapy in the 1980s. Due to software and hardware errors, the Therac-25 delivered massive radiation overdoses to several patients, resulting in serious injuries and deaths. Engineers failed to prioritize patient safety and overlooked potential hazards during the design and testing phases. A care ethics perspective would emphasize the need for engineers to prioritize the well-being and safety of patients above all else.

  Flint Water Crisis: In 2014, the city of Flint, Michigan, switched its water source to the Flint River as a cost-saving measure. However, inadequate water treatment and corrosion control measures led to lead contamination in the drinking water supply. This crisis disproportionately affected low-income and minority communities, highlighting issues of environmental justice and social responsibility. From a care ethics perspective, engineers and decision-makers should have considered the potential harm to vulnerable populations and taken proactive measures to prevent harm.

  Rana Plaza Factory Collapse: In 2013, the Rana Plaza garment factory in Bangladesh collapsed, resulting in over 1,100 deaths and thousands of injuries. The building's structural integrity was compromised due to unsafe construction practices and inadequate oversight. Engineers and building inspectors neglected their duty to ensure the safety of the workers, many of whom were women and children working in deplorable conditions. Care ethics emphasizes the need for engineers to prioritize the well-being of all individuals affected by their projects, including workers in global supply chains.

  Airline Safety Regulations: The implementation of rigorous safety regulations in the airline industry exemplifies a care ethics approach to engineering. Engineers, regulators, and industry stakeholders work collaboratively to develop and enforce safety standards that prioritize passenger well-being and minimize the risk of accidents. This collective effort reflects a commitment to caring for the safety and security of airline passengers and crew members.

  These cases illustrate the importance of incorporating care ethics principles into engineering practice to ensure that decisions prioritize the well-being and dignity of all individuals affected by technological developments.

- ➢ **Contextualism:** The idea that ethical decisions should consider the specific context and circumstances of each situation.

Environmental Impact Assessment: In a project involving the construction of a hydroelectric dam, engineers must consider the potential environmental impact on the surrounding ecosystem, including the displacement of wildlife, alteration of water flow, and disruption of local communities. Contextualism ethics would require engineers to weigh the benefits of clean energy generation against the potential harm to the environment and local inhabitants, considering the unique context of the project location.

Data Privacy in Smart Cities: Engineers developing smart city infrastructure, such as surveillance systems and data collection technologies, must navigate ethical considerations related to individual privacy rights. Contextualism ethics would involve assessing the specific cultural, legal, and social norms of the community where the technology will be deployed and tailoring privacy protections accordingly. Factors such as community values, regulatory frameworks, and potential risks must be considered in determining the appropriate level of data privacy safeguards.

Ethical Use of Artificial Intelligence: In the development of artificial intelligence (AI) systems for autonomous vehicles, medical diagnosis, or predictive analytics, engineers face ethical dilemmas regarding the potential consequences of AI decision-making. Contextualism ethics requires engineers to consider the unique contexts in which AI systems will operate, including the complexity of real-world scenarios, cultural differences, and the potential for unintended consequences. Engineers must assess the ethical implications of AI algorithms within the specific contexts of their application domains to ensure responsible and ethical use.

Community Engagement in Infrastructure Projects: When planning large-scale infrastructure projects such as highways, bridges, or airports, engineers must engage with local communities to address their concerns and incorporate their perspectives into the decision-making process. Contextualism ethics emphasizes the importance of understanding the social, economic, and cultural context of the communities affected by the project and involving them in the planning and design process. Engineers must consider the unique needs and values of each community to ensure that infrastructure projects are developed in a socially responsible and ethically sound manner.

Ethical Considerations in Global Engineering Projects: Engineers working on international development projects, such as providing clean water access or renewable energy solutions in developing countries, face complex ethical challenges shaped by cultural, political, and economic contexts. Contextualism ethics requires engineers to consider the specific socio-economic conditions, cultural norms, and governance structures of the communities they are serving and to tailor their engineering solutions accordingly. Factors such as local customs, resource constraints, and power dynamics must be considered to ensure that engineering interventions are culturally sensitive, sustainable, and empowering for the communities involved.

In each of these cases, contextualism encourages a nuanced analysis that considers the specific circumstances, values, and consequences relevant to the ethical decision-making process.

These advanced ethical principles offer a nuanced and multifaceted approach to ethical decision-making, providing individuals and organizations with a robust framework to navigate complex ethical dilemmas. By incorporating various ethical concepts such as Metaethics, Descriptive, and Normative ethics, students can develop a deeper understanding of ethical issues and enhance their decision-making abilities.

Engineering ethical cases frequently involve shades of gray rather than clear-cut distinctions between right and wrong. Moreover, determining ethical standards can be challenging. Key questions arise regarding the basis of ethical standards and their application in real-life situations. While personal beliefs, religious teachings, legal frameworks, and societal norms are often considered sources of ethical standards, history has shown that none of these alone is sufficient for making ethical decisions.

The initial step in addressing an ethical issue is recognizing its existence. Ethical dilemmas may not necessarily revolve around legality or efficiency but rather involve choices between conflicting alternatives, whether they are morally right or wrong. The framework outlined in the videos emphasizes the importance of recognizing ethical issues, gathering pertinent information, evaluating alternative courses of action, making decisions, implementing them, and reflecting on the outcomes. This systematic approach can aid individuals in navigating ethical challenges effectively and ethically.

Assessments

We utilized the rubric outlined in Table 1 to evaluate student learning outcomes. This rubric aligns with the criteria set forth by ABET for student outcome 4. Different sections of the rubric pertain to the introductory and advanced modules respectively. The focus of assessment in the introductory module is 4.1 (Identify ethical dilemmas or issues within an engineering context).

Introductory Module Assessment: The main objective of assessment for this module is to gauge students' ability to identify ethical dilemmas or issues within an engineering context. Assessment consists of two multiple-choice quizzes, allowing students two attempts to complete each quiz. The quizzes do not directly address unethical decisions within the cases; instead, they focus on assessing students' attentiveness and understanding of the case details. Figure 1 illustrates the results of the introductory level quiz for spring 2023.

Figure 1. Assessment results for introductory module

The results indicate that students initially attempted the quizzes without thoroughly reviewing each case. It is likely that they assumed the answers were straightforward. Upon failing the first attempt, they subsequently watched the videos and demonstrated improved performance on the second attempt.

Advanced module is a part of the capstone design course. The primary aim of assessment for this module is to evaluate students' proficiency in elucidating the ramifications of engineering choices within a global, economic, environmental, and societal framework. Furthermore, senior students are expected to propose strategies or responses to ethical dilemmas or issues in an engineering context, considering global, economic, environmental, and societal considerations. Sections 4.2 (Explain the impact of engineering decisions in a global, economic, environmental, and societal context) and 4.3 (Recommend actions or responses to an ethical dilemma or issue within an engineering context, considering global, economic, environmental, and societal context) are used to assess the advanced module.

Conclusion

This report is a work in progress, and we will continue refining the material and methods as we gain further insights. In the introductory module, our approach closely mirrors that of Clancy [11], which involves selecting an entry-level course, incorporating a laboratory module, and presenting simple cases to enhance students' awareness. However, due to resource constraints, the department cannot offer a comprehensive electrical engineering course covering all aspects of ethics and professional responsibility as suggested by Passino [10]. Instead, our advanced module emphasizes the nuanced nature of ethics, acknowledging that decision-making can be challenging. Furthermore, we introduce students to various ethical perspectives, recognizing that different groups may hold divergent views on contemporary issues, including ethics.

To streamline the learning process, both the material and assessments have been implemented online, allowing students to complete them independently. Moving forward, several areas warrant investigation:

a. We need to evaluate the efficacy of online material delivery. Would in-person discussions enhance learning outcomes?
b. A thorough assessment of these modules is necessary to gauge their effectiveness comprehensively.
c. We should consider transitioning our examples to focus exclusively on topics relevant to electrical engineering.

These steps will help us refine our approach and better meet the educational needs of our students in the realm of ethics and professional responsibility within electrical engineering.

Table 1. Assessment of student outcome 4

Outcome (4) An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts				
	Unsatisfactory (1)	**Developing (2)**	**Satisfactory (3)**	**Exemplary (4)**
(4.1) Identify ethical dilemma(s) or issue(s) within an engineering context.	Student is not able to identify ethical issues (dilemmas) in cases in a given scenario.	Student can identify basic and obvious ethical issues (dilemmas) in a given scenario but does not clearly describe them and fails to identify interrelations among the issues.	Student can identify major ethical issues (dilemmas) in a given scenario and clearly describes identifies some interrelations among the issues.	Student can identify several and complex issues (dilemmas) in a given scenario and clearly identify interrelations among the issues.
(4.2) Explain the impact of engineering decisions in a global, economic, environmental and societal context.	Student is unable to explain any of relevant Impacts of engineering decisions.	Student can explain the impact of engineering decisions relevant to only one context (global, economic, environmental, or societal) and describes it at only an elementary level.	Student can explain the impact of engineering decisions relevant to two or three contexts (global, economic, environmental, and societal) and at least two are sufficiently described.	Student can thoroughly explain the impact of engineering decisions relevant to global, economic, environmental, and societal contexts.
(4.3) Recommend actions or responses to an ethical dilemma or issue within an engineering context, considering global, economic, environmental and societal context.	Student cannot recommend ethical and professional approach when considering a given situation.	Student can recommend actions or responses considering only one context (global, economic, environmental, or societal).	Students can recommend actions or responses that consider two or three relevant contexts (global, economic, environmental, and societal).	Students can recommend actions or responses that thoroughly consider relevant global, economic, environmental, and societal contexts.

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