

Embedding Engineering Ethics in Introductory Engineering Courses using Stand-Alone Learning Modules

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Abstract

Ethics is a core principle of any service profession and in particular the engineering profession for the direct impact it has on human life and the environment. However, many engineering degree curricula rely on general education requirements (GER) to introduce and teach ethics to engineering students. More often than not engineering students take ethics-based courses in their junior year or later. Also, in many cases, such GER courses teach ethics based on fundamental theory and students cannot always connect it to engineering practice easily. To address this issue, many engineering course instructors have successfully introduced ethics-based learning modules in their courses, including introductory first-year courses. The authors have developed and taught an introduction to engineering design course to students in the general engineering program at the New Jersey Institute of Technology (NJIT). The general engineering program serves undecided and underprepared students. The authors have continuously upgraded and updated the course based on feedback and lessons learned. This paper presents a summary of various ways the authors have explored to teach engineering ethics to first-year students through a stand-alone module. Some of the successful modules include townhall style presentations, ethics debates, and more recently breakout sessions in response to the switch to remote instruction due to the COVID-19 pandemic situation. The paper will provide information on how to run these modules as well as the pros and cons of each of the methods attempted. We hope to help instructors quickly design and implement such modules in their course as well as to get valuable feedback on improving such modules in our courses.

Introduction

Employers of engineering graduates highlight their mastery of technical skills and their comfort level in executing hands-on activities, but also point out their lack of effective communication skills as well as experience in handling ethically challenging situations and making fact-based decisions. Many students do not have the opportunity to learn about engineering ethics and the dilemma it brings until they take higher-level courses. Engineering schools all across the world offer training to their students to prepare them to address ethical and moral dilemmas they will face in a professional setting. Some schools offer dedicated courses teaching the topics of engineering ethics and professionalism and others offer similar content broken down into modules embedded into in one or more engineering courses spread out over the curriculum. More so, Accreditation Board for Engineering and Technology (ABET) student 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” [1], reinforces the importance of teaching engineering ethics and professional behavior to undergraduate students. However, most common ways of teaching ethics to engineering students rely heavily on general education requirement courses that are offered by non-engineering departments often using non-engineering case studies and examples. In such courses, students are introduced to the philosophy and basics of ethical thinking and conduct but still are not able to make the connection between this theoretical study and real life practice of engineering. If the concepts of ethics are embedded into engineering and design

courses then students are more likely to make the connection and visualize themselves as future engineers navigating such challenging situations.

The goal of this paper is to provide a few ideas to the reader on how to embed engineering ethics seamlessly into engineering curriculum. The suggested ideas and activities are particularly recommended for first-year students in an introductory engineering course. Although, these ideas can be scaled to be implemented in higher level engineering courses as well. In addition, since the pandemic some of these ideas have been modified to cater to the transition to an online/converged classroom. The authors have now successfully implemented these ideas in engineering courses across all levels (first to senior year) at NJIT starting with their first-year design course. The authors will also provide details on running these activities in a remote environment. The following section provides a brief literature review on common approaches on teaching and introducing ethics in engineering classes.

Literature Review

The most common method of teaching engineering ethics is by using real-life case studies [2, 3]. Some common examples used are the Challenger space shuttle, 1974 DC-10 crash, and Exxon Valdez spill. Some instructors have been using case-studies that are specifically catering to the major of study. This helps in providing a better context to students [4-6]. Another interesting idea is to use videos/movies as a learning tool in an engineering ethics course [7]. Some common examples are hypothetical movies such as Ethicana, Henry's Daughters and Incident at Morales. In addition, commercial Hollywood movies such as The Informant and documentaries such as Seconds from Disaster: The Deep-Water Horizon can also be used. These videos/movies can enable a discussion on ethical dilemmas faced by characters or a certain situation encountered in them. High et. al. [8] have designed a class that uses video clips containing re-enactments of published empirical studies that demonstrate why people act unethically. Another common approach of teaching engineering ethics is by embedding it into a design course in the engineering curriculum [9-12]. A service learning design project is also a great way to expose students to ethics [13].

Ethics education has been taught to first year students using quite a few different and creative approaches to make sure that this population stays interested in this material. One approach is by suggesting an expert witness role-play based on traffic crash reconstruction. [14]. An engaging technique developed by Reeves and Nadolny [15] is where students take on various scientific roles and produce engineering reports in a hypothetical company in a make-belief world. Another unique and innovative approach that could be used to teach engineering ethics is developed by Hamlin et. al. [16]. They propose the idea of a phenomenological approach to teach engineering ethics where students examine what it is to be an ethical engineer through a series of readings about ethical engineers, personal interviews with engineers, and their personal reflection about their own character and values. Atwood and Read-Daily [17] propose a creative fiction assignment requiring the students to generate and reflect upon an ethical dilemma of personal interest, while exercising creativity and communication skills. Rossmann [18] introduces students to ethics using a risk assessment-based approach. This approach attempts to incorporate the basic questions of risk-benefit analysis with information on the decision makers, constraints and context, and implementation of the system. Finally, to increase student engagement, Burkey and

Young [19] have created a Cards Against Humanity style card game. Also Carpenter [20] has developed a board game called The Ethics Challenge which is similar to Monopoly. Both these ideas enable students to learn the material without losing interest.

A Few Ideas to Embed Engineering Ethics into Introductory Engineering Courses

The authors co-teach an introductory engineering design course at a mid-sized Science Technology Engineering Mathematics (STEM) focused university. All of the activities covered in this paper started out in this introductory course but have also been implemented successfully in higher level engineering courses across both in-person as well as remote instruction modes. In addition, the authors have also presented some of these ideas at American Society of Engineering Education (ASEE) affiliated conferences and subsequently upgraded them based on the feedback received [21, 22]. The following sections lists these ideas followed by general advice in planning these activities.

Idea 1: Town-Hall Style Presentations on Engineering Ethics Topics (based on [21]):

This original idea was a combination of two activities to teach students the importance of making fact-based presentations on engineering topics with an element of ethics involved, while simultaneously getting feedback from their peers and instructors to improve on their communication skills. Authors improvised this activity by selecting engineering topics with an element of ethics involved. This not only introduced students to the basics of ethical dilemmas faced by practicing engineers but also forced them to learn about making fact based decisions to take on such dilemmas. It is very important to dedicate a portion of the lecture before the activity to go over basics of ethics and how they apply to the practice of engineering. This activity is better suited for in-person classes but can be slightly modified to run effectively in remote teaching environment as well.

- 1) To encourage students to break the fear of public speaking, the authors invited the leadership team of the student chapter of Toastmasters Club. Toastmasters, an organization that operates clubs worldwide to help members improve their communication, public speaking and leadership skills, is very active on campus. This class visit by Toastmasters served three important purposes:
 - a. To help students improve their oral communication skills.
 - b. To encourage students to join the student chapter and continue to make improvements to their oral communication skills
 - c. To prepare students for the second activity – town hall style meeting.
- 2) The follow-up activity was a town hall meeting. This is a team-based activity where carefully chosen topics relating to current affairs (with an ethical challenge/dilemma embedded) were provided to students. Student teams were pre-assigned randomly a “for” or “against” side for each topic. Each team made a short oral presentation followed by a rebuttal/argument on their topic. The goal of these activities was to encourage students to improve their oral communication skills, public speaking skills, and simultaneously motivating them to understand facts about trending topics and ethical challenges associated with them. Students were also tasked with presenting these facts in an effective manner. The town hall activity was assigned two weeks before it was scheduled, and Toastmasters Club presented one week before the activity such that the students had the opportunity to learn some tips and tricks to

improve their oral communication skills and start to apply them the very next week. The town hall activity was structured to be carried out by choosing two groups for each topic where students were randomly assigned a topic from a pre-determined list. The activity was split into three parts and each part was allotted 2 minutes. Table 1 below explains the activity breakdown and the time allotted for each part.

Table 1. Town-Hall Style Presentation Activity Breakdown [21]

Activity Breakdown (Time Allotted)	Description
Activity 1 – Presentation by Toastmasters Club (30 minutes)	Leadership team of Toastmasters Club student chapter was invited to present to all students about the club and how joining the club can help students improve their oral communication and public speaking skills. The team also did a small exercise to engage students in a demonstration of some of the simple yet effective tips.
Activity 2 – Town Hall Meeting Part 1: First group presents in favor of the topic (2 minutes per team)	The first group presented their views by discussing facts and numbers to justify their stand. Emphasis was on presenting fact-based information regardless of their individual feelings about the topic that was assigned.
Activity 2 – Town Hall Meeting Part 2: Second group presents against the topic (2 minutes per team)	The second group presented their views in conflict to the views of their opponent by discussing facts and numbers to justify their stand.
Activity 2 – Part 3: Rebuttals/Discussion (2 minutes per team)	At the end of the presentation, the audience and the groups discussed about the accuracy of the facts and further received constructive criticism and feedback from the audience.

Some examples of topics used included- Use of Drones, Net-Neutrality, Self-Driving Cars, and Renewable Energy among others..

Student Feedback:

To help gauge the effectiveness of the activity and possible ways to improve it for the next semester, an online survey was distributed to the students,. The first part of the survey asked questions such as “The activity helped me work better in groups”, “The activity helped increase my understanding of engineering design process” and more. These questions requested a Likert scale response from 1-5 (1- poor, 5- excellent). The second part of the survey focused on whether students were able to improve/learn/explore themselves. Figure 1 summarizes the student responses.

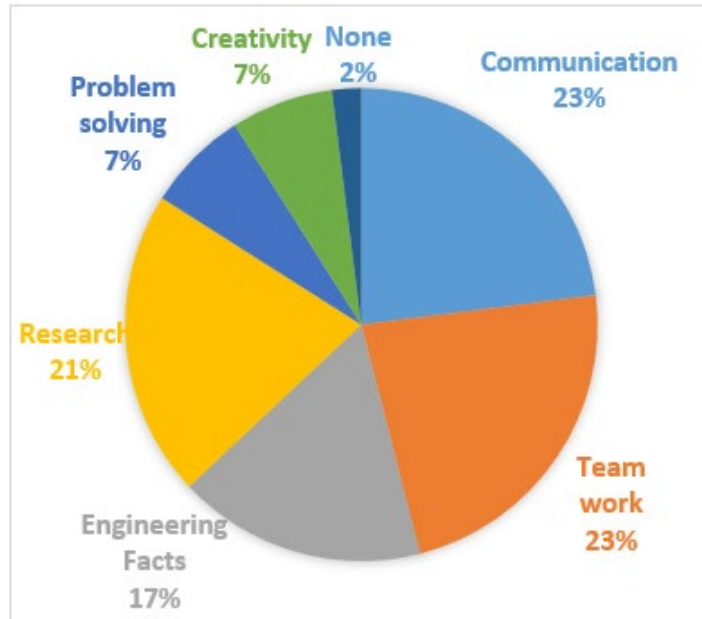


FIGURE 1

SUMMARY OF STUDENT RESPONSE (ACTIVITY HELPED ME IMPROVE...) [21]

General Advice for Planning the Activity:

1. Two minutes is a very short time for students to be able to make a strong pitch in first attempt. A mock rehearsal in the week before the actual town hall meeting will go a long way in improving effectiveness of this activity.
2. Students should be given precise feedback in order to learn what and how they could have done better.
3. Students often misunderstand and impulsively make a presentation based on emotions – it is important to iterate multiple times that the aim here is to make fact-based presentations.
4. Share the action plan, grading rubric, class breakdown, expectations, and tips to avoid common presentation mistakes as early as possible

Idea 2: Engineering Ethics Debate Activity (based on [22]):

This activity requires significant advance planning and six lectures (each one hour and 20 minutes long) to implement. The engineering ethics using one-on-one debates activity is planned in three parts – Part 1 - background theory, Part 2 - a mock debate, and Part 3 – student debate presentations to demonstrate their grasp on the topic. Details of all three parts are given in table 2 below.

Table 2. Engineering Ethics Debate Activity Breakdown [22]

Activity Breakdown (No. of Classes)	Description
Part 1 – Background	1. Introduction to engineering ethics and ethical dilemma often faced by practicing engineers through real life examples and case studies from

<p>Theory and Introduction (3 Lectures)</p>	<p>across the globe. Through this, students learned about some of the ethical theories and tests such as: the Basic Duties/Obligations by W.D. Ross [23-24], Bernard Gert's Ten Moral Rules [25], and Utilitarian Theory [26]. This background and introduction lecture focused on providing the students with some background knowledge and ethical decision guidelines to help them analyze and make a decision on the problems.</p> <p>2. At the end of the lecture series, students were asked to form groups (2 per group) and each group was assigned a fictional pre-prepared case study topics that contained scenarios based on real-life examples and a binary question for the team members to debate on.</p>
<p>Part 2 - Mock Debate (1 Lecture)</p>	<p>1. The instructors performed a mock debate. Topic of the debate was a popular dilemma (self-driving cars deciding a course of action during an unavoidable accident scenario) that was presented in a similar format to the topics assigned to student teams. The mock debate presentation concluded with tips on making effective presentations and improving oral presentation skills.</p>
<p>Part 3 – Student Debate Presentations (2 Weeks)</p>	<p>1. The class was split into a number of rooms such that each room was assigned 10-12 groups. This was to allow for sufficient time for each team to present their works within two classes. This also makes the number of case studies to be pre-prepared to a manageable number and each breakout room is still able to have each of the teams present on a topic that is unique to the audience.</p> <p>2. All debate presentations were designed to be 6-8 minutes of presentation time followed by 2-3 minutes for a Q&A session. This will allow for some time to provide immediate oral feedback to each team. This oral feedback should be followed by a written summary of comments later on.</p> <p>3. It is important to finalize and distribute the grading rubric ahead of time. The grading rubric focused on how well the debating groups explored the conflict, applied the knowledge they acquired during the lecture to pick sides based on facts and how well they supported their arguments with credible references among other things as appropriate. This ensures standardization of grading across breakout rooms while still allowing for the faculty/staff/TA judges in individual rooms to offer their own special perspective and comment on each presentation.</p>

The case studies covered ethical dilemmas associated with various commonplace topics including, automation, clinical drug trials, accidental eavesdropping, and political interference among others. Some examples of fictional titles for these case studies included- securing a contract in East Africa, excluding the undesirable, sharing preliminary clinical trial data, solar cells in Sumatra, and other ones based on real issues imagined in fictional scenarios. Each of these topics/case studies offered an elaborate story for students to put themselves in shoes of an engineering facing an ethical dilemma based on differences in culture, background, socioeconomic status among other things. Each case study also presented a unique binary question for students to explore, research, and present on.

General Advice for Planning the Activity [22]:

1. Plan ahead - coming up with fictional scenarios based on real life example for case studies can be a time consuming effort.
2. Reserve a few minutes at the end of mock debate presentation to make sure all students are clear on expectations and steps they have to follow to deliver an effective debate.
3. Students often misunderstand and impulsively make a presentation based on emotions – it is important to iterate multiple times that the aim here is to analyze the ethical dilemma using the theories and tests learned in class.
4. Share the action plan, grading rubric, class breakdown, expectations, and tips to avoid common presentation mistakes as early as possible. The tips to avoid common mistakes hand-out should be updated after every cycle.

Idea 3: Breakout Sessions to Explore the Role of Engineers in Major Global Events/Phenomena:

This activity is highly suitable for remote teaching environment (also called as synchronous online teaching environment) and takes advantage of the breakout session feature of the teaching portal (Zoom, WebEx, MS Teams, Google Meet or similar ones). Although, it can certainly be done quite effectively in an in-person classroom using group discussions to resemble breakout sessions from the online environment. In this activity, the students learn about a major global event or phenomenon and then explore how it is affecting the field and practice of engineering, how it is presenting challenging issues often involving ethical dilemma, as well as the role engineers and scientists must play in order to not only handle/tackle these issues but also to overcome them. The build-up lectures must include introduction to ethical theories and case studies selected should include how ethical dilemmas impact the practice of engineering. Based on the global event/phenomenon selected, this activity can be made highly relatable and thereby encouraging enthusiastic participation from students in the breakout sessions. Such presentation of important global topics and discussion in breakout sessions is supplemented by one or more assignments that require students to research and present data driven and fact-based solutions to major challenges faced by engineers. Table 3 below summarizes the breakdown of the activity.

Table 3. Role of Engineers in Major Global Events/Phenomena Activity Breakdown

Activity Breakdown (Number of Classes)	Description
Part 1 – Establishing Background on the Selected Topic and its Impact on the Engineering Field (2 Lectures)	<ol style="list-style-type: none">1. Students were introduced to major global events/phenomena that have had a profound effect on practice of engineering. These topics were appropriately complimented by the historical perspective on such events/phenomena and how our approach to take on such events/phenomena has evolved over time.2. Towards the end of each lecture, students are asked to join different breakout sessions to explore various aspects of the impact of the topic discussed on the practice of engineering.3. The lecture concludes with the rapporteur from each breakout session reporting a summary in the main room to the entire class.
Part 2 – Role of Engineers and Scientists in	<ol style="list-style-type: none">1. This part deals specifically with making recommendations based on data and evidence available on the challenge at hand. The lecture begins with a case study to help students understand the

<p>overcoming the challenge (1 Lecture)</p>	<p>expectations of the subsequent breakout session discussion as well as the homework assignment based on this topic</p> <ol style="list-style-type: none"> 2. Towards the end of the lecture, students are asked to join different breakout sessions with each focusing on a different case study for students to work on. 3. The lecture concludes with the rapporteur from each breakout session reporting a summary in the main room to the entire class.
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Some examples of topics used included- COVID-19 pandemic, vaccine distribution, climate change with specific examples such as recent power outage in Texas.

General Advice for Planning the Activity:

1. The choice of topic is very important. The topic should not only be well known and highly prominent but also should be prepared in such a way as to offer students multiple ‘Aha’ and ‘Wow’ moments throughout the overview presentation.
2. Efforts should be taken to keep the ‘impact on engineering profession’ thread woven throughout the presentation.
3. Strategically placed breakout sessions will keep students focused and engaged
4. If the homework is planned in such a way that the discussions in the breakout sessions are directly helping students brainstorm ideas for the solution then this will guarantee enthusiastic participation
5. It is ideal if each breakout session has a qualified moderator (instructor or TA) to keep the discussion moving forward while staying on topic.

Summary

This paper presents a few ideas that the authors have used to teach engineering ethics to general engineering students right in their first semester at NJIT. These ideas include running a townhall style meeting and conducting ethical debates in a face-to-face classroom, and doing breakout session discussions on a major global event in a synchronous online class. General advice on planning and running such activities successfully is also provided so that they can be easily replicated in any engineering classroom.

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