

## **Integrating Ethics into Engineering Education: A Case-Based Learning Approach**

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# **Integrating Ethics into Engineering Education: A Case-Based Learning Approach**

Abstract:

This paper introduces an innovative method for infusing ethics into senior design capstone courses within engineering education. Historically, the conventional approach involved introducing ethical concepts through lectures, followed by students individually preparing reports on case studies involving ethical considerations. These reports were presented to the class, and in-class discussions were conducted. However, the authors observed that the resulting discussions often lacked depth and thoughtfulness, prompting the development of a new approach to enhance the integration of ethics in senior design courses.

For this new approach, students were organized into teams of two and tasked with selecting a case from a provided list of recent case studies. They then created videos about their chosen case, which were shared on a learning platform for everyone to watch. A robust online discussion forum was established for each case study, whereby every student contributed an original discussion thread and engaged in at least two responses to a peer's contribution. In addition, students were actively encouraged to engage in questioning and responding within the discussion and not just limited to their particular case study.

The outcomes of this new pedagogical approach have been remarkably positive. The online format promoted increased interaction, richer and more profound discussions, higher participation rates, and well-thought-out responses. Students benefited from extended reflection and research time compared to traditional in-class presentations, resulting in a more comprehensive understanding of engineering ethics. This innovative method underscores the significance of case-based learning in instilling ethical principles and critical thinking skills in future engineers, ultimately contributing to the cultivation of responsible professionals in the field.

## **Introduction**

Incorporating ethics into engineering education, particularly in senior design courses, has been a topic of interest and research, for example [1]-[6]. The Accreditation Board for Engineering and Technology (ABET) requires that all accredited engineering programs must ensure their graduates possess the capacity to identify ethical and professional obligations in engineering scenarios and make well-informed decisions. These decisions must consider the consequences of engineering solutions in global, economic, environmental, and societal contexts [7]. The emphasis is on enhancing students' ability to confront social and ethical dilemmas in their professional lives, acknowledging the crucial role that ethical decision-making plays in engineering practice.

One approach is to integrate ethics and societal impact (ESI) issues directly into senior capstone design courses. This integration can be achieved through various methods, including dedicated lectures, discussions, and project work that emphasize ethical decision-making in engineering practice. According to a 2016 national survey [8], 40% of engineering faculty include ethics and societal impacts (ESI) in capstone design courses. ESI topics such as professional practice issues, safety, engineering decisions in uncertainty, and engineering codes of ethics are taught by

more than half of the instructors [8]. Engineering design projects (70%), in-class discussions (58%), case studies (58%), examples of professional scenarios (57%), and lectures (55%) were used to teach ESI [8]. Group-based written assignments (47%), individual reflections (33%), and individual homework assignments graded with a rubric (31%) were used to assess ESI learning [8]. Sixty-two percent of survey respondents believed that capstone design taught undergraduate students about ESI [8].

This paper proposes a novel approach to incorporating ethics into engineering education courses by having students choose a case from a list of recent case studies and create a video about it. To facilitate in-depth student discussions, asynchronous online discussion forums for each case study were established. This approach was implemented into a senior design capstone course, and its details are presented in the next section.

## Method

The method of incorporating ethics case studies with student-produced videos and robust online discussion forums was implemented in a senior capstone course at a four-year public, primarily undergraduate institution. We present it here in the context of a senior capstone course, but the method can be used in any course since it is independent of the senior design projects. Figure 1 shows an overview of the method, including the timeline used.

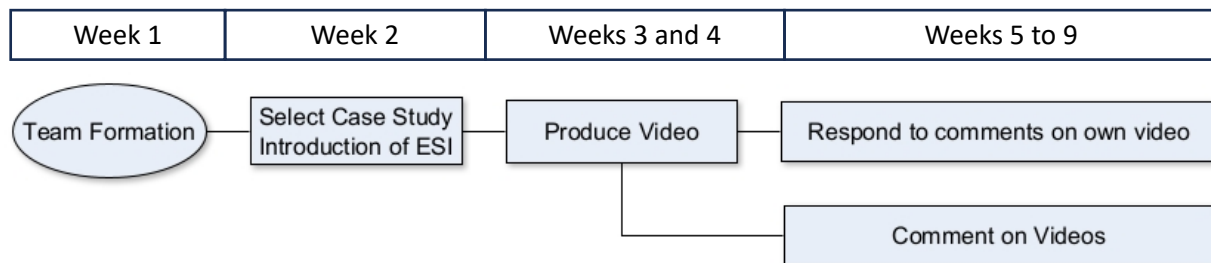


Figure 1: Overview and timeline of incorporating ethics case studies.

First, students were organized into teams of two. There was one three student team in our case because the total number of students in the course was an uneven number. Teams were instructed to choose a case from a provided list of recent case studies, spanning the last 15 years. Below are some examples from the selection:

- Tesla AutoPilot
- Hoverboard Batteries
- Millenium Tower
- Mitsubishi Fuel Economy
- Dakota Access Pipeline
- Chrysler Shifter
- Refrigerant 1234yf development
- Theranos Edison Blood Test
- Takata Airbag Recall
- Bay Bridge Bolts

Utilizing recent case studies enables students to establish stronger connections with the case because they were already born when it occurred. We used self-selected two-students' teams because, with only two students per team, each student will have a larger amount of responsibility for researching, creating the video, and writing responses. While larger, more diverse teams can offer a wider range of viewpoints, leading to more nuanced intra-team discussions, the increased individual responsibility in smaller teams can also foster a more in-depth grasp of the case study. Smaller teams also necessitate less coordination and communication, resulting in quicker progress and more efficient decision-making. In order to ensure that each team is assigned a unique case study, student teams were requested to complete a survey indicating their top three preferences for a case study. A one-hour lecture about ethics and societal impact, as well as the role ethical decision-making plays in engineering practice, was presented to the students in week 2.

Second, each student team was required to create a video presentation of their chosen case study. We gave students two weeks to create their video. We supplied the following prompt to encourage students to thoroughly research their case study before creating the video:

*Research your case study, including but not limited to, the following information:*

- 1. Determine the facts in the case study.*
- 2. Define the stakeholders.*
- 3. Assess the motivations of the stakeholders.*
- 4. Identify the major ethical implications.*
- 5. Determine which ethics code the case study violates.*

We gave the following instruction for making the video:

*Make a presentation to the class on the ethical implications of your case study. Explore the ethical questions related to the case and relate it to the codes of ethics. Your presentation should be professional and last approximately 10 to 15 minutes.*

*Focus on the ethical questions, not mistakes made by the parties involved! A mistake could be a calculation error by a junior (or senior) engineer. The ethical question might be: Should the engineer have been supervised and his/her work reviewed?*

*Make and record your video. Upload a link to the video for this assignment. You may use any technology that you find useful. The easiest may just be a recorded zoom meeting. Record to the cloud and submit the video link. Alternatively, you can upload it to YouTube and submit that link.*

*Bonus points for captioning your video.*

*SUBMIT with your video: ONE DISCUSSION QUESTION for the class to answer.*

The student-produced videos were shared on our course's learning management system (in our case, Canvas), where all students had access to and were required to view each video. The rubric shown in Figure 2 was provided to the students upfront and used by the instructors to grade the videos.

Criteria	Ratings					Pts
Voices clear and easy to understand	5 pts Excellent	4 pts Good	3 pts Fair	2 pts Poor	0 pts Very Poor	5 pts
Slides and/or other visuals are clear and readable	5 pts Excellent	4 pts Good	3 pts Fair	2 pts Poor	0 pts Very Poor	5 pts
Graphics/pictures are used effectively	5 pts Excellent	4 pts Good	3 pts Fair	2 pts Poor	0 pts Very Poor	5 pts
Case is clearly explained	5 pts Excellent	4 pts Good	3 pts Fair	2 pts Poor	0 pts Very Poor	5 pts
Ethics code(s) are applied to the case	10 pts Excellent	8 pts Good	6 pts Fair	4 pts Poor	0 pts Very Poor	10 pts
Ethical questions related to the case are addressed	20 pts Excellent	16 pts Good	12 pts Fair	8 pts Poor	0 pts Very Poor	20 pts
Captioning available? Bonus points	5 pts Yes		0 pts No			5 pts
Total Points: 55						

Figure 2: Rubric for grading video submissions

Asynchronous online discussion forums were established for each case study. Students were asked to:

1. *Watch all the videos for each group (except yours)*
2. *For each case study (except yours), post an original discussion post and reply at least once to a colleague's post. Please constructively add to the conversation.*  
*OR*  
*For each case study (except yours), reply at least twice to colleagues' posts. Please constructively add to the conversation. (i.e., you should be posting at least twice for each case study.)*
3. *For YOUR case study, reply to everyone's questions/post about your video. You may split the answering of posts between the group-mates).*

We gave the students 4 weeks to engage with the discussion forums. An example of a discussion prompt is shown in Figure 3 and the discussion post rubric is shown in Figure 4. The rubric was provided to the students upfront and used by the instructors to grade the discussions. Since there are two options for students, initial and post/replies or two replies, the total maximum score is 30 points.

30 points | Original Posts and Replies Due March 6, 11:59pm

Video and Discussion Question Creators: [REDACTED]

[Video Link](#)

Please locate the rubric by selecting the three dots at the upper right of this discussion, then select "Show Rubric."

## Instructions

After you watch the video for this case study, post a reflection to this forum. To do so, click the "Reply" button at the bottom of this screen. In your post please discuss 2 of the following questions:

1. Who should be held responsible for the safety of oil rigs?
2. What ethical responsibility did the BP engineers have in addressing the environmental damage that resulted from the disaster?
3. What questions do you still have?

Reply to at least one colleagues' posts. In each reply, please do the following:

1. Constructively add to the conversation
2. Try to leave emotion out of it. Address the topic, not the people writing the comment.

### OR

You can reply to two colleagues' posts following the above guidelines.

**If you are the creator of the video:**

Reply to everyone's questions/post about your video. You may split the answering of posts between the group-mates (~6/person replies).

Figure 3: Example of discussion prompt.

Discussion Posts Ethics   				
Criteria	Ratings			Pts
Initial Introduction Post	15 pts An original post is made before the due date that fulfills the required elements.	7.5 pts An original post is made before the due date but only partially fulfills the required elements	0 pts No Post	15 pts
Replies	15 pts One reply is made before the due date that fulfills the required element.	7.5 pts Reply does not fulfill the required element.	0 pts No replies are posted	15 pts
2nd Option: 2 Replies	30 pts Two replies are made before the due date that fulfill the required element.	15 pts One reply is made before the due date that fulfills the required element. OR replies don't fulfill requirements	0 pts No replies are posted	30 pts
Video Creators	30 pts Replies are made before the due date that fulfill the required element.	15 pts Replies don't fulfill requirements or not enough replies.	0 pts No replies are posted	30 pts

Figure 4: Discussion forum rubric.

To illustrate how these student-created videos are used in the discussions, a sample discussion thread is presented next. The chosen case study for this example is the BP Deepwater Horizon Disaster, see Figure 3. The video was created by [Author 1] and [Author 2]. In the following discussion, responses from other students will be labeled as [Student 1], [Student 2], and so on.

**[Student 1]:**

Hey [Author 1] and [Author 2],

I really enjoyed your presentation!

In response to the questions:

1. Who should be held responsible for the safety of oil rigs?

I believe that people at multiple levels should share responsibility for the safety of oil rigs. I think the most responsibility lies with the management at BP, who should ensure that oversights such as the ones that occurred are discovered before the oil rig is put into operation. However, some responsibility also lies with the engineers who did not fully consider many potential problems. I also believe that the government should closely regulate the design and operation of these oil rigs to ensure they operate safely.

2. What ethical responsibility did the BP engineers have in addressing the environmental damage that resulted from the disaster?

The BP engineers were responsible for approving cost-cutting measures that resulted in subpar construction and ultimately failure of the whole drilling operation. BP has a responsibility to avoid damaging the environment, and since the damage is already done, it is their responsibility to mitigate the effects of this damage as much as possible.

**[Student 2]:**

Hello [Student 1],

I saw that you mentioned that the BP engineers were responsible for approving the cost-cutting measures that failed the oil rig. To add to that, the BP engineers were ethically responsible to most importantly ensure that everything was going to function properly, especially since they decided to cut costs. The BP engineers also were ethically responsible for running multiple tests and inspections on the oil rig before making it fully operational as any failure can be catastrophic to the environment, in which it was.

**[Author 1]:**

Hi [Student 1]! Glad you enjoyed our presentation. I definitely agree that management and engineers at BP hold ethical responsibility for the disaster that occurred. Had government regulation been involved in the initial designs, it is possible that the safety issues, as well as the construction issues that resulted in many of the failures, could have been avoided. BP definitely had an ethical responsibility to aid in the clean up of the environment, and they broadly failed to properly act in this manner. Much of their actions at the time were related to reducing how much

they could be held accountable for the situation, instead of addressing the massive ecological and humanitarian crisis that the event created.

**[Student 3]:**

Hello [Student 1],

I agree with your answer on the responsibility for the safety of the oil rigs. This was a disaster that does not fall on one person, but rather on various groups that ignored the obvious. The managers, the engineers, and the government are all at fault. It's very peculiar that an operation of this magnitude was not carefully regulated by all of the parties involved. I understand that the operation was late and was not making money but rushing it and cutting corners ended up costing billions of dollars in damages. The first mistake was using the cement that was not adequate for handling such an operation. This should have been a mistake big enough to look into, yet they continued and made more along the way.

Looking at this and the other threads from this discussion, we can see that the tone of the discussion is respectful and collaborative. Students seem to be building on each other's points, which indicates a constructive dialogue. The students have effectively addressed the case's ethical dimensions, focusing on the responsibility of engineers and companies to prioritize safety and environmental protection. They have also discussed the ethical obligations of transparency and accountability, highlighting the importance of honest communication and the need for companies to take responsibility for their actions. Furthermore, the discussion touches on the broader ethical responsibility of engineers to prevent harm and protect public welfare, which is a key principle in engineering ethics. Overall, the discussion demonstrates thoughtful engagement with the ethical issues raised by the Deepwater Horizon oil spill. The students have shown an ability to analyze the situation from multiple perspectives and consider the ethical responsibilities of the various stakeholders involved.

**Discussion**

The method of incorporating ethics case studies with student-produced videos and robust online discussion forums has been implemented in the senior capstone course at [a four-year public institution] since 2021. For the purpose of the paper, we will focus on the particular course from 2023. This course had 17 students, resulting in 8 teams of two students each, except for one team of three students. We opted to assign discussion of all the ethics case studies to all the students, which meant that each student had to create a video for their ethics case study with their partner, as well as review the videos for the other seven case studies and engage in the discussion forums for each case study. The statistics of the discussion forums are shown in Table 1.



Table 1: Statics of discussion forums, 8 teams/case studies, total of 17 students.

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8
<i>Total posts</i>	39	41	41	43	41	42	43	38
<i>Initial posts (IP)</i>	12	14	13	13	14	13	14	11
<i>Word count IP</i>	1262	1755	1581	1554	1836	1809	1834	2030
<i>Avg. word count per IP</i>	105	125	122	120	131	139	131	185
<i>Replies</i>	27	27	28	30	27	29	29	27
<i>Word count replies</i>	2256	2168	2243	2373	2708	2280	1920	2656
<i>Avg. word count per reply</i>	84	80	80	79	100	79	66	98
<i>Total word count</i>	3518	3923	3824	3927	4544	4089	3754	4686
<i>Word count per post</i>	90	96	93	91	111	97	87	123
<i>Max. thread depth (replies)</i>	4	4	4	4	4	4	6	6
<i>Average thread depth</i>	2.25	2.00	2.23	2.31	2.00	2.23	2.07	2.45

As Table 1 demonstrates, we saw good engagement across all discussion forums. On average, each student wrote 19 posts, which is 21% more than was required, which corresponds to roughly 1900 words written by each student. We noted that giving students four weeks to engage asynchronously with the case studies—writing initial responses, replies and answering questions or commenting on posts about their own case study—resulted in high quality discussions. We expected that students would work three hours per week on this assignment throughout the nine weeks. Compared to our previous method, where we had in class presentations and discussions, we noted the following:

- Every student engaged in the asynchronous online discussion. Students can take their time to formulate well-thought-out responses, promoting deeper reflection and critical engagement with the case studies as opposed to the pressure of speaking up in in-class discussions. This can be particularly helpful for introverted students or those with language anxieties.
- Students studied each case study. Since there is a requirement to post or reply to each case study discussion forum, students had to watch the videos and read all posts before posting. This is notably different from previous in-class discussions where we noted that some students didn't read about a case study before coming to class and only relied on the given presentations, which did not result in very in-depth in-class discussions.
- High quality posts and discussion threads. The average initial post word count was 131, and the average word count for replies was 83. Since we implemented a rubric, see Figure 4, students knew they could not just write short replies such as "I agree" or "Great comment", etc. To get credit, students had to constructively add to the discussion, and they overwhelmingly did so in our case.
- Ease of assessing learning outcomes. Using the rubrics made assessing the learning outcomes related to engineering ethics simple, easy and less subjective compared to

previous assessment methods, e.g., assessing presentations and in-class discussion contributions.

- High quality videos. Overall, the students' videos were excellent. The videos are of higher quality in both presentation and content compared to previously used in-class presentations. Students may re-record and edit their video until it is satisfactory. Although we strongly encouraged students to practice their in-class presentations in the past, some students did not.

We want to reiterate that this approach can be implemented in any course, from first-year to graduate level courses. Having students create one video and review and engage with seven other case studies worked well within our given timeframe of nine weeks. We planned that students would dedicate three hours each week to this task over nine weeks. For larger classes, we recommend assigning students 6–8 case study discussions, assuming students have three hours per week to work on the assignment. If less than nine weeks are available, adjustments to the timeframes should be made accordingly. To help adjust to different scenarios, the following equations can be used to adapt the approach. The crucial factor is how much time students have to work on the assignment. We use hours per week (HW) in the following equations:

$$\text{Cases to assign per student} = HW \cdot 2.33 \quad (1)$$

$$\text{Weeks to create video} = HW \cdot 1.5 \quad (2)$$

$$\text{Weeks for discussions} = \frac{12}{HW} \quad (3)$$

The above equations are rough guidelines and should be adjusted as needed.

## Conclusion

In conclusion, this paper presents a novel approach to integrating ethics into engineering education through case-based learning. It uses the effectiveness of case-based learning and the advantages of asynchronous discussions to instill ethical principles in future engineers. By having students create and discuss video presentations of ethical case studies, the method promotes deeper engagement and understanding of engineering ethics. Results indicate increased participation, thoughtful discourse, and improved learning outcomes.

Students' videos were of higher quality compared to previous in-class presentations, and the asynchronous online discussions allowed students to engage in deeper reflection and critical engagement with case studies, promoting deeper understanding. Students studied each case study before posting, resulting in more in-depth discussions. High-quality posts and discussion threads were created, with an average word count of 131 and 83 for replies. In addition, the asynchronous online discussion forums provide a more equitable way for students to respond. In a synchronous setting, vocal or confident students can dominate the discussion, leaving quieter students unheard. The asynchronous discussions gave everyone a chance to participate, regardless of personality, communication style or language skills. Rubrics make assessing learning outcomes related to engineering ethics simple and less subjective.

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