The Future of Engineering Education
2024 Annual Conference & Exposition
Oregon Convention Center
Portland, OR . June 23 - 26, 2024
ASEE
Paper ID #43855

Do Social Justice Case Studies Affect Engineering Professional Responsibility?

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Do Social Justice Case Studies Affect Engineering Professional Responsibility?

Introduction

Engineers solve complex problems that incorporate specific constraints, including cost, time, federal regulation, racial and economic disparities, and political power. As we train our undergraduate students to solve these problems, it is required by ABET Student Outcome (4) that we provide them with "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]. Separate from ABET accreditation requirements, we wish our graduates to make informed choices during their professional activities, especially if they work in an environment in which they are asked by a direct supervisor to falsify data. Ideally, this ethics training is conducted within engineering courses.

At Loyola University Chicago (LUC), four social justice case study projects are embedded in the curriculum. In this study, we hypothesize that the U.S. Senate Hearing social justice case studies are effective in teaching engineering professional responsibility for several reasons. First, the case studies are taught as situative learning experiences, and consider professional practice through analysis of an engineering standard/regulation. During a situative learning experience, learning occurs through a collaborative activity, with knowledge presented within an authentic context [2, 3]. Second, Keenan's Model of Conscience Formation provides students with a framework for evaluating inequities in each case study. Finally, the social justice case studies facilitate critical consciousness regarding engineering practices. This provides students an opportunity to reflect on the inequity perpetuated through engineering irresponsibility and take critical action to identify unethical practices and articulate a socially responsible engineering approach. Engineering professional responsibility was measured using the Engineering Professional Responsibility Assessment (EPRA) instrument, before and after the case study project.

Background

Ethics is "moral principles" [4]. We define professional responsibilities, using the professional social responsibility development model, as "an obligation that an individual … has to act with care and objectivity, aware of the impacts of their action on others, able to see issues from the perspectives of others, and with particular attention to disadvantaged populations" [5]. Training in ethics and professional responsibilities varies between engineering institutions.

Engineering Ethics

Historically, engineering students have been taught engineering ethics. Engineering ethics is considered professional ethics, that is, "special morally permissible standards of conduct that, ideally, every member of a profession wants every other member to follow, even if that would mean having to do the same" [6]. These courses or modules begin with a discussion of U.S. engineering ethics codes, which were first issued by the American Institute of Consulting Engineers in 1911 and the American Institute of Electrical Engineers code in 1912 [7].

Engineering ethics codes stress public safety, health and welfare, protection of the environment, competency, honesty, and fairness [8]. Using these codes as a framework, the courses or modules also contain engineering ethics cases of simulated or real-world situations.

Critics of this training approach have shown over the years that engineering graduates do not refer to the ethics codes [9, 10]. Further, the faculty/administration and student perceptions of engineering ethics education delivery are not aligned. In a study conducted over 18 campuses, 110 faculty members and 123 students were interviewed in 90-minute focus groups; two administrators from each campus were also individually interviewed. While the faculty and administrators believed that the engineering ethics curriculum provided a "nuanced treatment of complex issues, their students reported "hearing simplistic, black-and-white messages about ethics" [11]. Due to observations of faculty approving or participating in unethical behavior, students also did not perceive the faculty as ethical role models. However, the faculty believed they were modeling ethical behavior [11].

Socially Responsible Engineering

To encourage critical reflection of engineering work, including the power structures and political issues that shape design decisions [12], Jon Leydens and Juan Lucena developed four criteria for engineering for social justice [13], and Jessica Smith adapted these steps for practicing socially responsible engineering [14, 15]. We list this socially responsible engineering framework below:

1. Understanding structural conditions and power differentials among specific stakeholders of an engineering project.
2. Contextually listening to all stakeholders, especially those who are marginalized, to understand their worldview and to grasp their needs, desires, and fears surrounding a specific project, decision, etc.
3. Collaboratively identifying opportunities and limitations of creating shared social, environmental and economic value for all stakeholders, especially those who are marginalized. This requires acknowledging when "value" is differently defined by stakeholders.
4. Adapting engineering decision-making to promote those shared values, acknowledging situations in which this is not possible and engineering projects should not move forward.
5. Collaboratively assessing activities and outcomes with those stakeholders [15].

A key assumption of this framework is that an engineer works for a company practicing corporate social responsibility (CSR), the commitment "to principles of accountability to community stakeholders, customers, suppliers, employees, and investors" [16]. In such a work environment, it is possible for an engineering manager to perform all five steps during the planning and permitting of new oil and gas facilities [15].

However, what is the outcome if an employer is not committed to CSR, but is merely providing the minimum disclosures required by the European Union's (EU's) Corporate Sustainability Report Directive law, which first applies to all large companies and all listed companies with EU operations in the 2024 financial year [17]? How can socially responsible engineering be applied if a company's fundamental performance criterion for choosing an engineering design is maximum profit? Two recent examples of design decisions that maximized profit are the Volkswagen Emissions fraud [18] and the Boeing 737 MAX fraud [19].

Social Justice + Engineering

As defined by Lee Anne Bell,

> Social justice is both a goal and a process. The goal of social justice is full and equitable participation of people from all social identity groups in a society that is mutually shaped to meet their needs. The process for attaining the goal of social justice should also be democratic and participatory, respectful of human diversity and group differences, and inclusive and affirming of human agency and capacity for working collaboratively with others to create change [20].

Sorby, Fortenberry, and Bertoline recently noted, in their call to revolutionize engineering programs and make them inclusive, that engineering educators must engage students by demonstrating how engineering curricula address students' social justice concerns [21]. Gen Zers, defined by the Pew Research Center as those born after 1996, are progressive, pro-government, welcoming of the growing racial and ethnic diversity in the U.S., and worried about climate change [22]. When social justice and engineering are combined (social justice + engineering), there are obvious overlaps with socially responsible engineering, including contextually listening to marginalized stakeholders and collaboratively identifying opportunities for all stakeholders.

Integrating social justice with engineering in the classroom is difficult, as most engineering educators do not possess the requisite social justice background. Some engineering faculty members have successfully conducted this integration, whether for a thermodynamics [23] or controls [13, 24] course. It is incredibly challenging to attempt this integration within an entire engineering program [25].

We propose an alternative integration. Rather than adding social justice directly into our engineering courses, we rely on a social justice core curriculum to provide a thorough social justice foundation. Through this core curriculum, students learn how to critically analyze social conditions. We then administer social justice case study projects within engineering courses to teach our students about the effects of technology on others. At LUC, this is possible because all 27 U.S. Jesuit universities possess a core (general education) curriculum based on social justice. In 1974, Jesuit General Congregation (GC) 32 decided to take a more active role in alleviating poverty and injustice. In 2008, GC35 called on Jesuit universities "to promote studies and practices focusing on the causes of poverty and the question of the environment's improvement" [26, 27]. At the 12 U.S. Jesuit universities with ABET-accredited engineering programs, the mean number of core curriculum courses is 11 ± 2 courses. At 9/12 of these Jesuit universities, including at LUC, a social justice-based ethics course is part of the core curriculum.

B.S. Engineering Program and Social Justice Case Studies

LUC's B.S. Engineering program is a general engineering program with specializations of biomedical, computer, and environmental engineering. Each specialization emphasizes a social justice application. For example, in biomedical engineering, students learn to design and test robust medical device software, in preparation for a medical device to be cleared or approved by the FDA. All patients should receive high-quality medical devices, regardless of their ability to pay. All Engineering courses are taught using a mandatory active learning style, which increases the retention of female students, students of color, and first-generation students [28-31]. Engineering course sections seat at most 24 students, to facilitate active learning.

Four social justice case study projects are embedded in the curriculum, specifically in the Introduction to Engineering Design first-year course, Experiential Engineering sophomore course, Electronics Circuits and Devices sophomore course, and Capstone Design I senior course. Each case study project has a different format, and contains written, presentation, and discussion components.

The U.S. Senate Hearing social justice case study is assigned by the first author during the Experiential Engineering sophomore course, which is taught by another instructor. This case study is worth 10% of the total course grade. Within each case study, each student is assigned a case study character. After investigating the character, a student writes a two-minute speech, incorporating quotes from the character and providing properly-formatted citations for the quotes. The speech is recorded using Zoom, and is watched by all students portraying characters in the same case study. Additionally, each student writes a 500-word expository essay as to whether a given engineering standard or regulation was upheld.

Each student also writes a 500-word expository essay as to which character is the most vulnerable and which character was the first to recognize the issue. According to James Keenan's Model of Conscience Formation, Vulnerability precedes Recognition, and both are required for Conscience (Vulnerability -> Recognition -> Conscience). Vulnerability is "the human condition that allows one to hear, encounter, receive or respond to the other, even to the point of being wounded." Recognition is "the ability to acknowledge the other's and our own humanity, as we develop a sense that the other in need is another human being." As activated by Recognition, Conscience is "the response to others in all their need and fragility, as well as in their capacity and promise" [32, 33]. On the day the project is assigned, based on the advice of James Keenan, SJ, the first author first provided the definitions of Vulnerability, Recognition, and Conscience [32], and then played a four-minute Black Lives Matter protest video, which included the protesters stating "Say Their Name" [34]. The first author then asked students: 1) Is Black Lives Matter an example of Vulnerability or Recognition?, and 2) Is everyone in our city and state vulnerable, as defined by this Model of Conscience Formation? In preparation for writing this second essay, the students then read a book chapter by Fr. Keenan [32].

During U.S. Senate Hearing discussions, students in character answer questions posed by two "Senators," who are the first author and another Engineering faculty member. The rubric associated with this project has five performance indicators: written speech, speech presentation, standard/regulation essay, vulnerability/recognition essay, discussion. All rubrics used by LUC Engineering use four levels of attainment: Exemplary, Satisfactory, Developing, Emerging (Table 1).

Table 1. U.S. Senate Hearing Rubric

ABET Student Outcome (3): An ability to communicate effectively with a range of audiences.

Performance Indicator	Exemplary	Satisfactory	Developing	Emerging
Written Speech (5 pts)	Well-chosen quotes revealing your persona’s true character have been woven into a compelling speech, and are accompanied by accurate citations.	Well-chosen quotes revealing your persona’s true character have been woven into a compelling speech, but are accompanied by inconsistent citations.	The speech contains some quotes and some citations.	The speech contains few quotes and few citations.
Speech presentation (5 pts)	Delivery is poised, controlled, and in character. Props (like dressing as the character) enhance the presentation.	Delivery is poised, controlled, and in character.	The student can generally be heard, with some eye contact.	Mumbling and no eye contact characterize the presentation.

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.

Individual Essay Response 1 (500 words of opinion, 5 pts)	Central idea is well-developed, and is accompanied by substantial evidence and critical analysis.	Central idea is generally present, and is accompanied by some evidence and critical analysis.	Central idea is vague, and is accompanied by some evidence and critical analysis.	Central idea is not present; very little evidence and critical analysis exist.
Individual Essay Response 2 (500 words of opinion, 5 pts)	Central idea is well-developed, and is accompanied by substantial evidence and critical analysis.	Central idea is generally present, and is accompanied by some evidence and critical analysis.	Central idea is vague, and is accompanied by some evidence and critical analysis.	Central idea is not present; very little evidence and critical analysis exist.
Panel Discussion (5 pts)	Working as a group, students provide thoughtful responses.	Some students individually provide thoughtful responses.	Student responses to questions are vague.	Students are unable to answer the questions.

This year's case studies were the Parajo River Levee Breach, Lahaina Fire, and Oroville Dam Collapse. The associated standards/regulations were California Urban Design Levee Criteria [35], IEEE National Electrical Safety Code [36], and Oroville Dam and Reservoir Report on Reservoir Regulation for Flood Control [37], respectively. Case studies and accompanying engineering standards/regulations are retired after national investigative reports or plea agreements are published. For example, during the Flint, Michigan Lead Poisoning Crisis, the Environmental Protection Agency Lead and Copper Rule was not upheld. During the Volkswagen Emissions Fraud, the U.S. Clean Air Act was not upheld. Before the Boeing 737 MAX Crashes, Boeing provided fraudulent data to the Federal Aviation Administration (FAA) so that the FAA determined a lower, and less costly, level of pilot training was required, per Title 14, Part 21, Subpart B of the U.S. Code of Federal Regulations.

Methodology

Per the IRB-approved protocol, after an Engineering course's final grades were posted, de-identified survey data were used for secondary analysis. Separately, after informed consent was obtained, students participated in a focus group.

Participants

During Fall 2023, 38 sophomores enrolled in two sections of ENGR 201: Experiential Engineering, offered during the third semester of the BS Engineering curriculum. Of these 38 sophomores, 12/38 = 68% identified as female and 32% as male.

Tools

U.S. Senate Hearing case study written and oral speech results were used to assess attainment of ABET Student Outcome (3): An ability to communicate effectively with a range of audiences. Case study essay and discussion results were used to assess attainment of ABET Student Outcome (4).

The Engineering Professional Responsibility Assessment (EPRA) instrument [38] was used to estimate students' social responsibility attitude, based on a model of professional social responsibility development [5]. The original instrument has 50 questions spread across three realms (personal social awareness, professional development, and professional connectedness), with answers using a 7-point Likert scale. The EPRA survey administered at LUC uses a subset of 16 questions from the professional development and professional connectedness realms. To gain a more detailed understanding of participant social justice case study experiences, the post-survey included an open-ended question: What will you remember most about this Case Study project?

Methods

To determine attainment of ABET Student Outcomes (3) and (4), rubric grades were collated for all 38 students and reviewed. The expected level of attainment for each performance indicator was 80% Exemplary or Satisfactory.

Students were given the option of completing an EPRA survey 18 days after the case study project was initially assigned, and again 32 days after the project was initially assigned, right after the project presentations. For completion of either survey, a student received +1 extra-credit point (worth 0.4% of total course grade). EPRA pre- and post-case study results were compared using paired *t*-tests. The second author reviewed the answers to the open-ended question and conducted an in-depth interview with a participant recruited by the Engineering department's administrative assistant. Participation in the focus group was incentivized by a $20 Starbucks gift card.

Results

In this section, the results of Student Outcome assessment, the EPRA survey, and qualitative analysis are described.

ABET Student Outcome Assessment

Overall, students performed well on this project. They delivered convincing speeches, and were very engaged in the discussion. The most difficult part of the project was reading an engineering standard and determining if the standard was upheld. As shown in Table 2, the scores for this Essay Response 1 were not as high as for Essay Response 2. The threshold of 80% Exemplary or Satisfactory was obtained for four out of five performance indicators.

Table 2. Assessment For ABET Student Outcomes (3) and (4)

Student Outcome Being Assessed	Performance Criterion	% Exemplary or Satisfactory	Threshold Reached?
Student Outcome (3)	Written Speech	84	√
	Speech Presentation	97	√
Student Outcome (4)	Individual Essay Response 1	71	
	Individual Essay Response 2	95	√
	Panel Discussion	97	√

EPRA Survey Analysis

To test the hypothesis that participation in the social justice case study would increase participants' sense of engineering ethical and professional responsibility, we examined whether a statistically significant change occurred in each of the 16 EPRA item-observed scores from pre-case study to post-case study (Table 3). Of 38 students, 32 completed the pre-case study survey and 34 completed the post-case study survey. Only 29/38 students completed both surveys.

Of the 16 pairwise *t*-tests, only one pre- to post- change was statistically significant at the $p < 0.05$ level (item 8, "I would not change my engineering design because it conflicted with community feedback") and this mean difference was of medium magnitude (pre mean = 3.2, pre SD = 1.5; post mean = 2.5, post SD = 1.1; Cohen's $d = .54$). Thus, participating in the social justice case study increased participant's willingness to change engineering design that conflicted with community feedback, which is one indicator of an increase in a sense of engineering ethical and professional responsibility.

Table 3. EPRA survey data for students (n=29) who completed the pre- and post-case study surveys.

	Pre-Case Study Mean (SD)	**Post-Case Study** Mean (SD)
Base Skills Subscale		
How important are Fundamental Skills (i.e., Math & Science) for a professional engineer?	6.4 (0.6)	6.5 (0.5)
How important are Technical Skills (i.e. Conducting Experiments, Data Analysis, Design, Engineering Tools, & Problem Solving) for a professional engineer?	6.7 (0.5)	6.7 (0.6)
How important are Business Skills (i.e. Business Knowledge, Management Skills & Professionalism) for a professional engineer?	5.7 (1.0)	6.0 (0.8)
How important are Professional Skills (i.e. Communication, Contemporary Issues, Creativity, Leadership, Life-Long Learning, & Teamwork) for a professional engineer?	6.4 (0.6)	6.4 (0.6)
How important is Ethics (i.e. ensuring your work follows professional codes of conduct) for a professional engineer?	6.6 (0.5)	6.6 (0.6)
Analyze Subscale		
Cultural Awareness/Understanding (i.e. of your culture and those of others) is important for a professional engineer.	6.4 (0.6)	6.4 (0.9)
Societal Context (i.e., how your work connects to society and vice versa) is important for a professional engineer.	6.4 (0.6)	6.6 (0.9)
I would not change my engineering design because it conflicted with community feedback. *	3.2 (1.5) *	2.5 (1.1) *
It is important for engineers to consider the potential broader impacts of technical solutions to problems.	6.6 (0.5)	6.6 (0.5)
It is important to incorporate societal constraints into engineering decisions.	6.0 (1.1)	6.1 (0.9)
Professional Connectedness Subscale		
Volunteerism (for professional and personal reasons) is important for a professional engineer.	5.6 (0.9)	5.8 (1.2)
It is important to me personally to have a career that involves helping people.	6.6 (0.7)	6.4 (0.6)
I will use engineering to help others.	6.8 (0.4)	6.6 (0.6)
The needs of society have no effect on my choice to pursue engineering as a career.	2.5 (1.2)	2.8 (1.4)
Engineers should use their skills to solve social problems.	5.8 (1.0)	5.9 (1.2)
It is important to use my engineering abilities to provide a useful service to the community.	6.4 (0.6)	6.4 (0.6)

Notes:

- Response options for each Base Skills item were: 1 = Not at all Important; 2 = Low Importance; 3 = Slightly Important; 4 = Neutral; 5 = Moderately Important; 6 = Very Important; 7 = Extremely Important.
- Response options for each Analyze or Professional Connectedness item were: 1 = Strongly Disagree; 2 = Disagree; 3 = Somewhat Disagree; 4 = Neither Agree Nor Disagree; 5 = Somewhat Agree; 6 = Agree; 7 = Strongly Agree.
- * = statistically significant difference, $p < 0.05$

Qualitative Findings of the Post Case Study Open-Ended Responses

Of the 34 participants who provided a response to the question about what would be most remembered about the case study, 26 participants explicitly referenced ethical reasoning, civic (community) responsibility, and engineering professional responsibility in their responses.

Participant responses highlighted the effectiveness of the ethical aspects of the social justice case study. For example, one participant's response highlights the importance of an ethical imperative in engineering, "*How important it is for us engineers to work with morals and not differentiate between communities by their income. I also understand how important honesty is in work.*" Similarly, participant responses highlighted the consequences of unethical engineering practice, "*I will remember the consequences we learned about not acting ethically as* [an] *engineer because it could cause you to be sued as well as have damaging impacts on communities,"* "*I will remember how important it is to not falsify data and to do what is ethically and morally right,"* and "*... allows us to visualize how individual actions and more responsibilities play into engineering standards, regulations, and protocols."*

Participant responses also highlighted that they resonated with the civic responsibility focus of the social justice case study. Participant responses included, "*I will remember to use my engineering skills to help others and think about others before making decisions," "... engineering projects can affect the community and environment if not dealt with caution. Engineering projects that involve infrastructure also need a lot more care and attention than one would think.," "How important engineering is, and the effect it can have on peoples' lives either positively or negatively," "How important it is to consider the community in our services will affect, as well as ensuring that the projects that we help build are mode to successfully run while posing minimal to no negative effects toward the people and environment in which something could be installed/used,"* and *"I will remember the effects that my actions have on the people I am trying to help. I will have a person-first mindset rather than a fiscal mindset."*

Perhaps the importance of incorporating professional responsibility in the social justice case study can be best exemplified by this participant response, *"What will stick with me most is the constant reminder that real people could be affected by my mistakes and assumptions as an engineer."* Many participants resonated with the importance of recognizing the need for engineering professional responsibility such as, *"I will remember that going against regulations will lead to consequences, maybe not to the person who went against it, but innocent civilians."* The case study was memorable for participants who realized the very serious nature of engineering practice such as "*I will remember that engineering work effects every aspect of life. So, we need to take into consideration all groups no matter how big or small,*", and "*…the deadly and disastrous consequences of cutting corners in the engineering industry."*

Qualitative Interview

To gain a more nuanced understanding of the social justice case study experience, we attempted to recruit students who recently completed the social justice case study assignment; one student agreed to participate. The interview consisted of six open-ended questions. When asked what they will remember most about the case study project, the participant mentioned that the primary takeaway from the project was the social justice implications of engineering and how the student resonates with the way in which the engineering program focuses on the betterment of the world and not just on student growth.

When asked whether there were moments they reflected on ethics, civic responsibility, and/or justice and equity during the case study project, the participant stated that "… *one thing that was always coming to mind was the really big gap between resources for people in lower income communities… trying to find ways to like streamline better resources for those communities."*

Next, when asked whether they felt as though any of the reflections or lessons learned about the ethics and civic responsibility were relevant for them and/society beyond the engineering context, the participant discussed the tension in the realization that although they and other students likely felt comfortable discussing ethics and making responsible engineering decisions in a hypothetical classroom context, what was less clear was whether they would be able to act in the same ethical and responsible manner in the real world. "*…Okay, well, we know it's bad. But like, if we are being paid like in the real world for this job, like would we have the same reaction? Or do we like fear for our security of our own job, or like our family, like taking care of them.*" The participant felt that this aspect of the case study was helpful because, "*… as college kids like, it's kind of hard to put ourselves into that position… we were all like, 'oh no we would never do that' but it was something like we wouldn't really know how we would react to it until we are put in that position… so I think it's good that we are like exposed to these scenarios as students, because if we didn't have this knowledge* [before] *getting into the real world… I think I'd be more worried about my job security".*

Next, we asked whether they felt as though this experience deepened their understanding of privilege and/or oppression in society. The participant discussed how the case study helped them reflect on, "*how like unfair people can be treated simply because of the land just isn't worth as much… and it is just something I never really thought about until this past semester* [during the case study project]. "*…We studied the levee collapse that happened in California, and looking at the data it was like the government was giving options… 'we can fix the levee in this area that affects the low income communities, or we can protect like the higher income communities'… and they chose to like ignore the lower income community."* The participant shared how the case study was helpful at revealing privilege and oppression, "*Yeah, it is like privilege hides in places where you don't always expect it to be."*

When asked whether participating in the case study project provided them with a meaningful and transformative learning experience, the participant discussed how they have, "*… always like, kind of focused on social justice… has always been something that is important to me,"* and how this project "*… bring, like into, my… understanding where disparities in different parts of the world* [exist]*… so I think it is beneficial*."

Finally, we asked how they might explain the importance and impact of this case study project to someone outside of engineering. The participant's response highlighted how engineers have a professional responsibility to complete a task or project that will benefit other people, "*… but it is not just about completing the task… it is about completing it in a way that benefits like* *society as a whole. And so what the case study does is it helps us learn more about the areas of the world, or like groups of people that were aren't like aware of in our daily lives, and just keeping them in our minds when are working in the environment…. Just like to think of all types of people that you may be working with and that may be impacted by your decisions as an engineer."*

Discussion

For each performance criterion associated with the U.S. Senate Hearing social justice case study, the majority of students scored at the Exemplary or Satisfactory level. Only Individual Essay Response 1, in which each student described if the engineering standard associated with the assigned case was upheld, had less than 80% of students reach the Exemplary or Satisfactory level. This is a difficult question for sophomores to answer, as engineering standards are difficult for underclassmen to read. Also, students always assume an engineering standard was violated, since it is part of a case study. However, the Oroville Dam regulation was actually upheld. Next year, in the spirit of continuous improvement, the first author will provide past examples of engineering standards that were upheld, even though a disaster occurred.

To test directly whether participation in the social justice case study increased participants' sense of engineering professional responsibility, we compared pre-case study EPRA item scores to post-case study EPRA scores. Only one of the 16 pairwise *t*-tests was statistically significant (item 8, "I would not change my engineering design because it conflicted with community feedback") and the post-case study change was in keeping with our a priori hypothesis (i.e., suggested an increased willingness to attend to community feedback regarding engineering design).

The EPRA results in Table 3 do demonstrate that LUC Engineering sophomores in our study reported relatively high levels of professional responsibility, with all item level observed mean scores at the higher range (after accounting for reverse scoring) of the scale. It appears that the item-level observed scores in our study are greater in magnitude than in a priori EPRA. In the EPRA change study of 446 students, the average pre- and 1.5 year score for the Base Skills, Analyze, Professional Connectedness subscales was 5 or 6, using a 7-point Likert scale [39]. For EPRA positive-type responses, LUC sophomores had higher scores of 6 or 7. Future research could conduct measurement invariance tests to examine directly whether the magnitude of item-level means are statistically different across LUC Engineering students and non-LUC engineering students.

Perhaps the more compelling evidence for the impact of the social justice case study project comes from the student responses to an open-ended question about memorable aspects of the experience. Collectively, student responses highlight the ways in which the project facilitated reflection related to ethical reasoning, civic responsibility, and engineering professional responsibility and that these experiences deepened the learning and commitment to socially responsible engineering practice. Numerous student responses suggest that the social justice core curriculum also likely influences and magnifies the impact of the assigned social justice case study, which is ultimately critical-consciousness raising. The majority of U.S. engineering programs do not mandate that their students take 9 to 13 social justice-based core courses, as do

Jesuit engineering programs. Responses suggest that this attention to social justice and equity was a compelling component of the learning experience. This experience provides students an opportunity to reflect on the inequity perpetuated through engineering irresponsibility and take critical action to identify unethical practices and articulate a socially responsible engineering approach.

The effectiveness of these case studies may be due to the use of situative learning, and consideration of professional practice through analysis of an engineering standard or regulation. Real world engineering designs require standards to be met and regulations to be upheld. Working with an engineering standard in this case study as a sophomore lays the foundation for working with a standard as a senior during a capstone project, which is required in ABET-accredited engineering programs. It is also worth noting that the effectiveness of the social justice case study project could also explained in part by the broader core curriculum at LUC that consists of 12 courses that integrate social justice principles. These 12 core courses provide a social justice foundation that is combined with the effects of engineering technology in this social justice case study project.

The use of Keenan's Model of Conscience Formation was essential for students to empathize with the concerns of others. This model provides a framework for being able "to respond to others in all their need and fragility, as well as in their capacity and promise" [32]. In 2022, this model and accompanying question of vulnerability were introduced in the U.S. Senate Hearing Case Study project. However, since the students only learned about the model through the book chapter reading, they were unprepared to write an expository essay about the most vulnerable character in the case study. In 2023, the first author sought Fr. Keenan's advice on how to introduce the model effectively. He recommended starting with a Black Lives Matter video and discussion, and expanding the essay question to who was the first to recognize and who was the most vulnerable. These small changes gave the students an ethical framework for understanding engineering actions.

As previously stated, case studies and accompanying engineering standards/regulations are retired after national investigative reports or plea agreements are published. Another advantage of using recent disasters, like the 2023 Parajo River Levee Breach and 2023 Lahaina Fire, is that they circumvent the use of ChatGPT for the project. When ChatGPT was asked "Was the engineering standard upheld before the Pajaro River Levee failed?," its response in August, 2023 was:

> As of my last knowledge update in January 2022, I don't have specific information about the Pajaro River Levee failure or any related incidents after that date. Levee failures can be caused by various factors, including inadequate engineering standards, lack of maintenance, natural disasters, or unforeseen circumstances.

Study Limitations

It is worth noting that the small sample size in our study could have prevented us from detecting true post-case study change due to low statistical power [40]. However, it is also worth noting that our findings are similar to a prior EPRA change study that tracked 446 engineering students over 1.5 years. In pairwise *t*-tests for each subscale item, there was no statistically significant EPRA change pre- and at 7 months of the study [39]. Future studies – adequately powered with larger samples – could examine further the impact of social justice case study projects and their efficacy in bolstering students' sense of engineering professional responsibility. It is worth noting that although none of the responses to the open-ended questions indicated a negative experience (e.g., disliking the assignment or not learning anything from the assignment), the absence of such responses does not necessarily rule out the possibility of negative experiences. Similarly, although the focus group was advertised several times, only one student agreed to participate and although the participant provided in-depth responses, there may have been other experiences and perspectives that would help to explore the impact and effectiveness of the case-study assignment. Future studies could explore further diverse student experiences of the social justice case study projects.

Conclusion

Helping engineering students develop and deepen their sense of engineering professional responsibility is a critical task for engineering programs. LUC's Engineering program takes a novel approach of social justice case study projects to provide students with learning experiences that facilitate the discussion and reflection of ethical principles, civic responsibility, and ultimately engineering professional responsibility. Emerging quantitative and qualitative evidence highlights the ways in which the social justice case study project enhances student learning experiences and suggests that the experience may help develop and deepen student commitment to socially responsible engineering practice.

Acknowledgement

The authors would like to thank James Keenan, S.J. for his advice on how to incorporate his Model of Consciousness Formation into the U.S. Senate Hearing social justice case study.

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