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Civil And Architectural Engineering Students' Conceptualization Of Good Engineering And Its Implications For Ethics Education

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CIVIL AND ARCHITECTURAL ENGINEERING STUDENTS' CONCEPTUALISATION OF GOOD ENGINEERING AND ITS IMPLICATIONS FOR ETHICS EDUCATION (RESEARCH)

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ABSTRACT

The ways in which students conceptualise what it means to do good engineering illuminates their values and priorities and shapes their understanding of ethics in engineering. The present study is part of a larger project that is exploring civil and architectural engineering students' understanding of ethical and societal responsibility and its development via formal and informal learning. Data collection and analysis are ongoing in the larger project, and the present study focuses on eight semi-structured interviews with civil and architectural engineering students at one university in Belgium. The analysis was designed to address how civil and architectural students conceptualise good engineering and the potential role of the engineering culture in this meaning-making. The data were examined through the lens of Cech's culture of disengagement: a framing for how engineers conceptualise their professional responsibility and understand what it means to be an engineer. The findings include good engineering has a human-centred purpose, is responsible, and requires interpersonal competencies, all of which diverge from the tenets of the culture of disengagement. However, in alignment with the framework, there is evidence that students perceived gatekeeping in their programme to determine who

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can do good engineering. The implications raise awareness around the culture of engineering and point to students' interest in using it for community benefit.

1 INTRODUCTION

1.1 Background

There are many arguments for the integration of ethical and societal issues in engineering education. From accreditation to industry pressure to societal expectation, ethics is considered an important part of “good engineering.” However, what constitutes good engineering can be ambiguous. For example, “a good engineer is an engineer who cares about doing good engineering” (Davis 2015, 5). These broad ideals about good engineering can be especially challenging for students to interpret with limited engineering-related work experience. The values and norms around what constitute good engineering are culturally constructed and therefore turning an eye to culture can indicate what good engineering means and how students come to internalize it.

1.2 Theoretical Framework

Undergraduate education is a period of socialization through the processes of adapting to the engineering culture, assuming the identity, and showing unity with others (Dryburgh 1999). The culture of engineering thus informs the ways of knowing and being that students are formally and informally learning. Culture describes a group’s values and beliefs (Schein 1996), which in the context of this study, can explain how “good engineering” is conceptualised.

The present study is framed in the culture of disengagement (Cech 2014) to explore the inter-relationship between definitions of good engineering and their implications for engineering ethics education. The culture of disengagement is a set of practices and beliefs that inform engineers’ understanding of their responsibility to the public, and it has epistemic implications for how engineers value knowledge. Cech (2014) used longitudinal data from engineering students at four universities in the United States (US) to understand students’ public welfare beliefs and how they changed over time, the extent to which the programme culture emphasizes public welfare, and whether the programme emphasis related to students’ beliefs. This worked concluded that “engineering education fosters a culture of disengagement that defines public welfare concerns as tangential to what it means to practice engineering” (45). The culture of disengagement is propped up with three pillars. (1) Depoliticization frames “non-technical” as irrelevant, and a potential bias, to real engineering. (2) Technical-social dualism separates social considerations and privileges the technical. (3) Meritocratic ideology indicates that existing social structures are fair and just, and those who do not succeed deserve their outcome. The culture of disengagement contributes to engineering students leaving their programme less committed to public welfare than when they began: it underpins an understanding of good engineering as being technical, meritocratic, and unbiased from social and political dimensions.

1.3 Research Question

The research is guided by the following question: how do undergraduate civil and architectural engineering students conceptualise good engineering?

2 METHODOLOGY

2.1 Project Context

The present study is part of a larger project that is exploring undergraduate civil and architectural engineering students' conceptualisation of ethical and societal responsibility (Polmear 2022). The larger project includes semi-structured interviews with civil and architectural engineering students at one university in Belgium and one in the United Kingdom (UK) to explore students' understanding of the impact of engineering and the responsibility of engineers, including experiences inside and outside the classroom that shape it. As part of a constructivist grounded theory approach (Charmaz 2014), data collection and analysis are ongoing in parallel to develop emergent theory. The present study focuses on the interviews conducted in Belgium.

2.2 Data Collection

This study employed semi-structured interviews and took a cross-sectional approach to include participants at every level of their Bachelor's studies in civil and architectural engineering. Participants were recruited through an email the faculty, emails to professors in the programme, and visits to the design studio to speak to students. Through these processes, eight students scheduled and completed interviews in April and May 2022, and their information is provided in Table 1. The research was approved by the Ethics Committee for Human Science.

Table 1. Participant Information

Pseudonym	Year in Programme	Gender
Anna	2	Woman
Brigitta	2	Woman
Hann	2	Woman
Henriette	2	Woman
Joris	2	Man
Naomi	3	Woman
William	1	Man
Wallorroo	2	Woman

The following questions, as part of a broader scoped interview, were designed to understand students' ideas around good engineering. The questions were contextualized in their own journey and career plan to make the responses more specific to their experience, rather than about engineering in general.

- Can you describe your journey into (civil or architectural) engineering?
- Looking to after graduation, what are you hoping to do in your career?
- In the context of (their career interest), how would you describe good engineering?

- Can you give an example of what you consider good engineering?

2.3 Data Analysis

The first step in the analysis was generating complete transcripts from the audio recordings using an online service. I then verified the accuracy and removed identifying information. I conducted the data analysis in Dedoose, a web-based qualitative and mixed-methods analysis platform. The thematic coding following multiple cycles (Saldaña 2013). The first cycle was deductive with the codes informed by the three pillars of the culture of disengagement: (1) depoliticization, (2) technical-social dualism, and (3) meritocratic ideology. Recognizing that much of the data fell outside of these codes, the next steps was inductive coding to capture the emergent student conceptualisations of good engineering. The final cycle of coding was thematically grouping the data within each code to identify salient patterns. Through this cycle, I identified four themes that address how civil and architectural engineering students make meaning of good engineering through the framing of the culture of (dis)engagement.

2.4 Positionality

I recognize my positionality, which is constructed through my identity and perspective, impacts the research process and warrants transparency (Secules et al. 2021). I conducted the interviews and analysis, and the ways in which I engaged with the students and interpreted the data were influenced by my position inside and outside the research context. My academic training in civil engineering helped me understand the culture and curriculum and establish common ground with the students. However, my understanding of the broader culture and education system in Belgium was more limited since I was not born nor education there. Throughout the interviews, the students and I worked together to establish common understanding. For example, if they were not able to find a word in English (all were native Dutch speakers) or I was not familiar with the name of an organisation or programme on campus, we would take care to explain.

2.5 Limitations

One consideration in interpreting the findings is that data collection was not designed with the analytical framework in mind. The framework was employed *ex post facto* to understand students' conceptualisations of good engineering within a broader conversation around ethical and societal responsibility. It is also worth noting Cech's framing was developed and tested in the US context. Despite the globalisation of the engineering workforce, distinct engineering cultures exist in different countries. For example, the types of knowledge and jobs that are valued in France, Germany, the UK, and the US are different (Downey and Lucena 2005).

Another consideration is the data were collected at a single moment in time. The quantitative data in Cech's study were longitudinal and showed the decline over time of students' public welfare commitments. Future work could take a longitudinal and qualitative approach in the Belgian context.

3 FINDINGS

The findings are presented in four themes with representative participant quotes to address the research question.

3.1 Good engineering has a human-centred purpose

When asked to consider what defines good engineering, three students shared the perspective of it being human-centred and purpose-driven. As an example, Hann stated:

> *That's good engineering because you don't need a lot of steel to make this thing. Or you can think good engineering as in this building, this thing has a purpose, it's doing something good for people. I think that's both equally as important kind of. But I do tend to focus on the human aspect. Yeah, I think a good example of what I don't want to do is what they do in Dubai, those giant skyscrapers to show prestige. I would not feel good if that was what I would do in a few years.*

Hann went on to contrast skyscrapers in Dubai to the types of projects she wanted to work on as an engineer: affordable housing to address the current housing crisis. Henriette similarly defined good engineering in terms of an example of a professor who designs temporary shelters for people to use during humanitarian crises, like the war in Ukraine, and said “that’s someone who inspires me.”

William also shared that good engineering addresses “Who do I want to give it to? What do they need? Is it really the right place to place it there?” He provided the example of a course project for which he spoke with the community for whom he was designing the building. Through these conversations, William learned the community members wanted a clean space to talk and sit, so his design prioritized those features. Across these examples, good engineering meant addressing people’s challenges and being attentive to their needs. It is also important to note that students’ interest in using engineering to help others increased during their programme. When asked about their initial motivation to study engineering, none of the students mentioned pro-social commitments. The most common response was an interest in combining math and creativity. It was only upon entering the programme that students gained this perspective of what good engineering can do, such as Brigitta who said, “It was after I started that actually realized, ‘Okay, this is what engineer can do.’"

3.2 Good engineering is responsible

For two of the students, good engineering meant being responsible. As an example, Anna shared

> *Good engineering, I think, an engineer has a lot of responsibilities. Take the example of a bridge. If there's something wrong in a little calculation, the bridge could fall, and the engineers behind it are at fault.*

Her comment reflected the importance of technical responsibility (the “calculation”), responsibility to safety (the bridge falling), and responsibility in terms of “fault.” Joris also understood good engineering as a responsibility, which he explained as,

> *I think, first of all, good engineering means that you didn't forget anything or anyone. Something I've learned is that engineers have a lot of things to worry about… You have to think about so many things, not only about how it looks and if it would break down or not, you also just have a certain responsibility and that's something we've learned especially in the second semester of this year, that engineers really have a certain responsibility with them.*

For Joris, responsibility meant being holistic and inclusive in your approach. Students were asked later in the interview about responsibility in engineering, but these responses above were shared before I mentioned “responsibility.”

3.3 Good engineering requires interpersonal skills

A third theme I developed from the codes was the importance of interpersonal, social skills to good engineering. As an example, Anna shared

> *A good engineer also has to be creative, I think, because we have to have a problem-solving mind. That's very important, I think. I think we have to be also good at working together because we can't do everything alone. I think that's a very important part of engineering, is co-working and good communication.*

Her comment reflects creativity, problem-solving, teamwork, and communication as facets of good engineering. Naomi similarly emphasized teamwork,

> *Good engineering, I think working in a group is a very important thing, because it's not one person that has to do all the calculation. But it's like a group thing.*

These interpretations of good engineering speak to the creative, collaborative nature of engineering practice that requires skills in communicating and working with others.

3.4 Gatekeeping who can do good engineering

Thematic analysis of the codes related to meritocracy indicated gatekeeping in engineering education that determines who can enter and continue in the programme. For Joris, this gatekeeping starts before the programme as he explained,

> *Well in order to even start with this course you have to do something called the [name of exam], it's basically a test where they evaluate how much you already know about mathematics, chemistry and physics. And based on that grade you kind of have an idea if you are smart enough to complete.*

Joris’ comment alludes to the meritocratic structures of the system that use an exam to determine who is “smart enough” to do an engineering degree. For Naomi, this evaluation of who belonged continued throughout the programme.

> *I won’t say it has been as easy journey… The profs do have an opinion of your work, and it's kind of subjective. Also with the design studio, so I also in my*

> *second year, I had to stop at design studio, because I was so […] The profs were so hard on me. And last week, I had a conversation with a girl, and she said to me, 'Yeah, five people stopped with design studio, and a couple of people stopped with the study because of the professors'… but a lot of people also go through that. And they stop, and they can't handle with it, so stopping is the only thing they could think of.*

Naomi dropped out of the programme during her second year (and later returned) because she struggled with how the professors treated her, in particular the harsh and seemingly subjective feedback she received in the design courses. Naomi's experience, which was shared with other classmates, speaks to the culture of engineering education that serves as gatekeeping for what constitutes good engineering and who can stay in the programme long enough to do it.

4 DISCUSSION

This research explored civil and architectural engineering students' understanding of good engineering through a qualitative approach. The analysis was framed in the culture of disengagement (Cech 2014) to examine the interplay between good engineering and public welfare reasonability. Through thematic coding of semi-structured interviews, I identified four themes related to students' conceptualisations of good engineering. These themes are situated in the analytical framework and existing literature to develop implications for engineering ethics education.

The first theme, good engineering has a human-centred purpose, marks a difference from the culture of disengagement. Students' priority of addressing human needs does not align with the culture of disengagement pillar of depoliticization in which social and political considerations are disconnected from "real" (i.e., good) engineering. Students wanted to use engineering to address politically and socially fraught challenges, like housing and humanitarian crises, rather than bracket those concerns, and this interest increased through the programme. In Cech's work, on the other hand, students' commitment to public welfare declined over time. This divergence warrants future research to understand the longitudinal nature of students' perspective in the Belgian context. An implication of this finding is the power of the engineering programme in cultivating, not diminishing, these commitments to public welfare. Students cited examples from their courses where they learned about engineering being used to address social challenges that were attentive to people's needs. Such examples, whether the focus of a project or a brief mention, can carry weight for how students understand good engineering and engineering for good.

Another point of departure between the data and framework relates to the third theme: good engineering requires interpersonal skills. This perspective does not align with the culture of disengagement pillar of technical/social dualism that separates and devalues social competencies. Although a few students noted the importance of problem-solving, none of them conceptualised good engineering in terms of technical mastery but rather emphasized creativity, communication, and

collaboration. Although the broader discourse in engineering education reflects the implicit, and sometimes explicit, devaluing of professional and social competencies (Berdanier 2022), students in the present study acknowledged their importance. One implication of this finding is for engineering educators to continue emphasizing professional competencies, integrating them in technical courses, and providing opportunities for students to develop them.

Lastly, there was evidence of meritocracy in the data in terms of structures (and individuals) that determine who is allowed in and through the programme and can thus do good engineering. Gatekeeping has long been acknowledged as an issue in engineering (Main, Johnson, and Wang 2021)(Weston 2022) while concerns around engineering culture and student mental health have grown recently (Jensen and Cross 2021). Understanding the implicit and explicit ways that students are told whether they belong in engineering has important implications for individual students and education as a whole. Future work can continue to explore meritocratic norms in related to good engineering and ethics education.

5 SUMMARY

This research explores civil and architectural engineering students' understanding of good engineering and its interplay with the culture of disengagement and ethics education. The findings include good engineering has a human-centred purpose, is responsible, and requires interpersonal competencies, all of which diverge from the tenets of the culture of disengagement. However, in alignment with the framework, there is evidence students perceived gatekeeping in their programme to determine who could do good engineering. The implications raise awareness around the culture of engineering and point to students' interest in using engineering for good.

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