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Empathic approaches in engineering capstone design projects: student beliefs and reported behaviour

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ABSTRACT

Engineering design decisions have non-trivial implications, and empathic approaches are one way that engineers can understand and translate the perspectives of diverse stakeholders. Prior literature demonstrates that students must develop empathic skills and beliefs that these skills are important to embody empathic approaches in meaningful ways. However, we have limited understanding of the relationship between students' beliefs about the value of empathy in engineering decision making and how they describe their reported use of empathic approaches. We collected qualitative data through interviews with ten undergraduate engineering students in capstone design. We found that our participants espoused a belief that empathic approaches are valuable in engineering design decisions. However, while students considered diverse perspectives when describing how they made design decisions, their reported behaviour during design decisions did not demonstrate translation of their empathic understanding. Based on these findings, we provide recommendations to educators and researchers.

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Engineering design; decision making; empathy; capstone; beliefs

1. Introduction

Engineering design decisions have strong implications on a wide variety of stakeholders and, therefore, engineering students must learn how to use empathic approaches when making decisions. The design process includes both implicit and explicit decision making (Akin and Lin 1995) and these decisions affect diverse stakeholders such as workers, communities, and society (Vallero and Letcher 2012). For example, it was reported recently that more than 6500 migrant workers have died in the process of preparing Qatar to host the FIFA World Cup in 2022 (Pattisson 2021), in which engineering firms have been some of the 'key perpetrators in creating such "harms" against Nepales and other migrant workers.' (Millward 2017, 675). Because of the considerable implications of engineering work, scholars have voiced the need to educate students about responsible decision making (Nair 1997) and to provide them with listening skills that would allow them to understand stakeholders' perspectives when making design decisions (National Academy of Engineering 2004). The accreditation of undergraduate engineering programs requires that students develop an ability to 'meet specified needs with consideration of public health, safety, and welfare' (ABET 2020, 2). Without learning how to consider diverse perspectives for social and humanitarian purposes, engineering students risk failing to understand the design implications on people and the broader context (Mazzurco and Daniel 2020).

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As such, empathic approaches to design decisions are a concrete way for students to consider the implications of their design from the perspectives of diverse stakeholders. Empathy in design can simply be thought of as the 'capacity to step into other people's shoes, to understand their lives, and start to solve problems from their perspectives' (IDEO 2015, 22). In engineering education, perspective-taking – a skill aligned with empathy – has been shown to be a promising way to incorporate stakeholder perspectives into the decision-making process (Hess, Strobel, and Brightman 2017). Empathy in engineering can serve as a way to transition the field towards becoming more caring and just (Gunckel and Tolbert 2018).

To contribute to extant research on engineering students and empathy in design, this study explores (1) the beliefs that engineering capstone students espouse about the value of empathic approaches, (2) how students report behaving in ways that are considered to be empathic, and (3) the comparison between students' espoused beliefs and reported behaviour. We used qualitative methods to collect and analyse interviews with ten senior-level undergraduate engineering students towards the conclusion of their capstone design courses. By better understanding the relationship between students' beliefs and their reported behaviour about design decisions, engineering education can gain insights into the cultural and pedagogical limitations of engineering students' exposure to empathic approaches within undergraduate education.

2. Background

Empathy is an important skill in engineering design because it allows engineers to understand the perspectives of diverse stakeholders and incorporate these understandings into their design solutions. Engineering designs are fundamentally about meeting user needs (Koskinen, Battarbee, and Mattelmeaki 2003) and different stakeholders have different needs. Therefore, to provide solutions that address diverse needs, it is necessary to learn how to understand different perspectives (Kouprie and Visser 2009). Further, empathy has been recognised as a skill that allows engineers to consider the implications of design decisions on people (Zoltowski, Oakes, and Cardella 2012) and can serve as a way to address sociocultural and political aspects of the designs (Gunckel and Tolbert 2018). Theoretically, empathic approaches include recognising the emotional state of the stakeholder (affective), intentionally working to understand the perspective of the stakeholder (cognitive), and then acting based on the understanding gained from the stakeholder (behavioural). The affective and cognitive domains of empathy are acknowledged by Davis (1983), where the affective domain encompasses recognising the emotional state that is related to the other person's situation (i.e. affective sharing), and the cognitive domain refers to being intentionally aware of and understanding another person's perspective. The behavioural domain is recognised by Gerdes and Segal (2009), who argued that the affective response towards another person and the cognitive process of the situation allows the person to take empathic action. Ultimately, empathic approaches to design decisions can enable engineers to act upon the understanding they gain from stakeholders (Walther, Miller, and Sochacka 2017).

Based upon scholars' work on empathy within engineering (Walther et al. 2020; Walther, Miller, and Sochacka 2017), embodying empathic approaches in engineering requires the concurrent development of beliefs (which have implications for the affective and cognitive domains of empathy) and behavioural domains of empathy. In other words, embodying empathy requires students to develop their empathic skills (behaviour), and their understanding of what it means to be an engineer and what it means to do engineering work (Walther, Miller, and Sochacka 2017). Several scholars have provided frameworks and pedagogical approaches that can be used to develop students' empathic skills (i.e. behaviour). Kouprie and Visser (2009) provided a four-phase process where the designer steps into the life of the user, wanders around, and then steps back with a deeper understanding of the user. The steps include discovery, immersion, connection, and detachment. Similarly, Fila and Hess (2015; 2016) identified design steps that support students' abilities to leverage empathy in design, including developing empathic understanding, identifying criteria and constraints, generating design concepts, and evaluating design concepts. However, in order for students to understand why developing their empathic skills is necessary in engineering, we need to explore students' beliefs about the role engineers play when making design decisions and the role that empathy plays in engineering – characterised by Walther, Miller, and Sochacka (2017) as 'ways of being.' More recently, Walther and colleagues studied how engineering students made sense of empathy while they learned about empathic communication in a design course. They found that while students perceived the empathic modules as valuable, they still were uncomfortable and questioned the role that empathy plays in engineering (Walther et al. 2020). They demonstrated that it is difficult to separate the behavioural and beliefs domains when teaching students about empathy because students' beliefs about what it means to be an engineer had implications on their perceptions of empathy. Without developing empathy on multiple levels (e.g. beliefs and behaviour), engineering students risk failing to fully utilise empathic approaches to translate their understanding of diverse perspectives into their design solutions.

Because congruence between behaviour and beliefs is needed to support engineering students' ability to embody empathic approaches to design decisions, it is relevant to specifically study both what students believe as well as how they report behaving, and the relationship between these two constructs. For this purpose, we present our research here as a contribution that extends the literature on empathy in engineering by asking our participants about both domains, specifically addressing the following research questions:

RQ 1: What do students believe about the value of empathic approaches to engineering design decisions?

RQ 2: When describing their capstone design decisions, how do students report behaving in ways that are considered empathic approaches?

RQ 3: What is the relationship between these beliefs and reported behaviour?

3. Theoretical orientation: beliefs and reported behaviour

We used two distinct constructs to study empathic approaches to design decisions: beliefs and reported behaviour. While some researchers contend that beliefs can be used to indirectly predict behaviour with 'a considerable degree of accuracy' (Fishbein and Ajzen 2011), others have shown that what people say they believe does not necessarily align with their enacted values or behaviour (Bazerman and Tenbrunsel 2012; Polly and Hannafin 2011; Yerrick, Parke, and Nugent 1997). By collecting data and analysing both beliefs and reported behaviour, we are able to draw conclusions about (1) what participants state explicitly as their beliefs about the value of empathy in engineering, (2) the ways in which participants describe using empathy during their capstone, and (3) the relationship between their beliefs and reported behaviour.

Three decades ago, Pintrich (1990) argued that beliefs are the most valuable construct to study in education. Since then, educational research has investigated the role of beliefs in engineering. For example, considerable research has established the importance of understanding students' beliefs about: their own capabilities (i.e. self-efficacy) (Hutchison-Green, Follman, and Bodner 2008; Lent et al. 2008; Marra et al. 2009; Michael, Booth, and Doyle 2012; Purzer 2011), the self (i.e. identity) (Eliot and Turns 2011; Jorgenson 2002; Pierrakos et al. 2009; Tonso 2006), problem solving (McNeill et al. 2016), the nature of knowledge and knowing (Cunningham and Kelly 2017; Faber and Benson 2017; Pavelich and Moore 1993; Pavelich and Moore 1996), and beliefs about the nature of intelligence (Blackwell, Trzesniewski, and Dweck 2007; Dringenberg and Kramer 2019; Dringenberg, Shermadou, and Betz 2018; Dweck 2000; Reid and Ferguson 2014; Stump, Husman, and Corby 2014). Ultimately, Smith (2016, 89) argues that, 'We cannot escape our beliefs; they shape our every response to our every situation.' In educational research, beliefs are often studied quantitatively using established instruments from fields like educational psychology. When studied qualitatively, beliefs as a construct are often not explicitly defined.

For this study, we operationalised beliefs as the assumptions that individuals make about reality, or their assumptions about how the world is, which is in alignment with the previous work on empathy in engineering that we are drawing on for this research (Walther et al. 2020). More specifically, we considered students' beliefs to be their explicitly stated assumptions, or their *espoused* beliefs, about the value of empathic approaches in engineering decisions. Our focus on espoused beliefs aligns with our methodological approach using retrospective interviews with students and is in contrast to any attempt to access more deeply-held or implicit beliefs through methods such as constructing arguments (Kuhn 1991). To complement our investigation of students' espoused beliefs, we also investigated the role that empathic approaches played in students' reports of their own behaviour for design decisions. To be clear, we did not actually observe students' behaviour, but rather relied on their perceptions of what they did and why, as they recounted their experiences in interviews. As a research construct, reports of behaviour are more closely aligned with enacted beliefs, or the beliefs that come through in one's behaviour. This distinction for operationalising beliefs is important because there is considerable evidence showing that a gap often exists between *espoused* and *enacted* beliefs, or *behaviour*, as cited above.

4. Method

This study is a component of a larger project that focuses on studying undergraduate engineering students' beliefs about diverse approaches to engineering decision making, which includes empathic approaches (along with rationalistic and intuitive approaches, which are not a focus of this contribution). Participants were recruited from a large, U.S. Midwestern university using short, in-person presentations during the beginning of senior capstone courses across multiple engineering disciplines. We specifically sought participants from various disciplines due to how the different undergraduate engineering programs and coursework may play a role in students' beliefs about the value of empathic approaches for their capstone projects. For example, we recruited from both mechanical engineering and biomedical engineering based on the likelihood that different disciplines have different 'distances' of engagement with stakeholders. As such, it might be easier for biomedical engineering students to consider the implications of their design decisions for a medical device than it would be for mechanical engineering students in their semi-permanent fixture within a mechanical system. We distributed flyers to the students that provided information about the study and a link to where students could indicate their interest in participating by completing a short participation survey. A total of ten undergraduate students from different disciplines and types of capstone projects indicated interest in participating and all of them were recruited to participate in the study; their demographic information is provided in Table 1. Out of 14 engineering majors at the university, we were able to successfully recruit from five majors, including our desired variation across disciplines. Women were overrepresented in our sample, which the reader should

Table 1. Demographic information of our participants.

Pseudonym	Gender	Disciplines	Types of Capstone Project
Anna	Female	Mechanical Engineering	Reduce anxiety on car driver
Brian	Male	Chemical Engineering	Create bioplastic for automotive company
Carlton	Male	Information Science, minor in Engineering Science	Reduce anxiety on car driver
Darcy	Female	Biomedical Engineering	Detect obstacles for powered wheelchair users
Elfrieda	Female	Biomedical Engineering	Detect obstacles for powered wheelchair users
Felicia	Female	Mechanical Engineering	Create a device for rowers with amputation
Grace	Female	Mechanical Engineering	Solution for public restrooms
Heather	Female	Biological Engineering	Create bioplastic for automotive company
Isabella	Female	Biomedical Engineering	Create a more comfortable seat for automotive company
James	Male	Mechanical Engineering	Create a project based upon Internet of Things

note when considering transferability of the research findings to their respective student bodies. Each student selected their own pseudonym for a given letter of the alphabet. While some capstone projects were similarly described by students, we did not ask if they were members of the same design team due to confidentiality purposes. Therefore, while students might describe team dynamics for their design decisions, we cannot assume that these students were related to each other based on the descriptions given.

We collected qualitative data during the last three weeks of the academic semester, and the first author (Guanes) conducted all the one-on-one, hour-long interviews. She asked students to talk about a specific instance where an explicit decision had to be made between multiple options for their capstone projects, and where none of those options were clearly right or wrong (i.e. the decision was ill-structured). By providing this definition for the decision to discuss, we were ensuring that the participants were describing the types of design decisions that were key to the final design, as opposed to logistical or inconsequential decisions within the design process. The interviewer then asked students to provide a description of the role that different approaches played in a design decision in the context of their capstone project, including empathic approaches. During the interview, we defined empathic approaches as 'considering the decision from another person's perspective.' Thus, when answering the second research question, 'how do students report behaving in ways that are considered to be empathic?', our participants were the ones deciding how they *behaved* empathically by explaining the perspectives they considered. Besides asking about a concrete decision, the interviewer also asked students to talk about how engineers should make decisions, which included students' interpretation on how empathic approaches should be used to make engineering decisions. We compensated participants with a $20 gift card for participating in the interview. Our interview protocol is provided in Appendix 1.

The audio recordings were transcribed via a professional transcription service. During the initial reads of the transcripts, we sought to understand students' beliefs about multiple approaches to design decisions (rationalistic, intuitive, and empathic). We noticed an emergent pattern in the ways that students talked about empathic approaches as valuable to engineering design decisions, but the actual use of empathic approaches seemed to be missing in how they described their behaviour during their design decision-making process. Thus, the contribution in this paper is the result of our systematic investigation of this pattern that was initially noticed in the context of the larger research project. We should note that this project was exploratory and we used general approaches to qualitative data analysis rather than a particular qualitative methodology, which aligns with the nature of our research questions – explore students' beliefs about diverse approaches to decision making. Our data analysis team (one faculty member, two graduate students, and an undergraduate student) performed an initial phase of data condensation (Miles, Huberman, and Saldaña 2014) by reading the transcripts in full and identifying the components of the transcripts where students talked about empathic approaches. This included their espoused beliefs about the value of empathic approaches in engineering as well as their reports of using empathic approaches (or not) within their actual capstone design projects. We then did another round of data condensation using a descriptive coding approach (Saldaña 2016). Our descriptive coding was guided by questions (provided in Appendix 2) focused on characterising both espoused beliefs and reported behaviour. This step in the analysis process was completed iteratively for all ten transcripts, individually analysed by two team members (a graduate student and an undergraduate student), and then discussed with an additional graduate student for process reliability (Walther, Sochacka, and Kellam 2013). During the process reliability discussions, the two team members that coded the interviews presented their initial codes, compared codes, and resolved any differences with support from the other graduate student. From there, we grouped the codes and generated abstracted themes as a form of data presentation analysis (Miles, Huberman, and Saldaña 2014) to present the findings coherently; these themes are presented in Section 6 as the answers to our first two research questions. Finally, we performed second order analysis (Saldaña 2016) in order to describe the relationship between students' espoused beliefs and reported behaviour, answering our third research question.

5. Limitations

The transferability of our study to other settings is limited by several factors. First, we acknowledge that capstone design might be approached differently amongst disciplines and taught differently by instructors, even across the world. Thus, beliefs about empathic approaches might be different in students from other majors and countries. However, research has shown that despite variations in pedagogical approach and emphasis, students' broader beliefs about the field of engineering are consistent across diverse contexts (Cech 2014; Niles et al. 2020). In our case, we were only able to recruit from certain engineering majors, including biological, biomedical, chemical, and mechanical engineering and engineering science. Further, the students we recruited were participating in either interdisciplinary (mechanical and biomedical engineering) or multidisciplinary capstone courses (e.g. business), which has implications for students' experiences that cannot be controlled in our research design. In relation to context, our study also oversampled women in engineering, who might have different perspectives about empathic approaches than, e.g. White, cis-gendered men in engineering. Second, our data only enables us to draw conclusions about students' espoused beliefs, which may or may not align with their more deeply-held or implicit beliefs. This is a limitation because we know that people are often unaware of their implicit beliefs, even though they inform our conduct in real-world settings (Connors and Halligan 2015; Smith 2016), and these more deeply-held beliefs can be transmitted through the hidden curriculum (Bejerano and Bartosh 2015; Polmear et al. 2019; Villanueva et al. 2018). Third, we also acknowledge that courses such as capstone design provide students with limited time to work on their projects and, therefore, might affect the decisions students make when working on their design projects. Lastly, our data is limited to students' interviews and what these interviews captured. Thus, we did not collect data on the context in which these students were embedded (e.g. their instructor or what they were taught).

6. Findings

When asked about the role of empathic approaches in their design and engineering broadly, students espoused the belief that empathic approaches are valuable to engineering design decisions to consider the potentially harmful impacts on people broadly and to align the design with needs of specific users. When describing their reported behaviour, while students discussed considering a variety of stakeholders during their capstone design projects, they ultimately described prioritising the perspectives that impacted them as students for their design decisions (e.g. instructors). In the following sub-sections, we provide detailed descriptions of each of these key findings supported by excerpts from our interviews along with our discussion points.

6.1. Findings for RQ1: students' beliefs about the value of empathic approaches to engineering design decisions

Our participants espoused a common belief that empathic approaches are valuable for engineering design decisions. More specifically, they conveyed a belief that empathic approaches are valuable on two different levels: (1) to consider the potential harmful impact of engineering decisions on people broadly, and (2) to align the design with the needs of specific users.

6.1.1. Consider potentially harmful impacts on people broadly

When asked about the role of empathic approaches in their design and engineering broadly, students conveyed a belief that empathic approaches are valuable because they enable engineers to consider the broad impact that their design decisions have on people. Students expressed this belief by describing how engineering design decisions have the potential to impact or even injure people. These descriptions were general rather than specific and were exemplified in cases where the decisions directly affected people, such as building a bridge or a building:

> … There are a lot more parties involved in broad decisions of how you design things. Whether it be, building a bridge—the broader decisions of how you're going to implement that affect who's working on it, how much they work on it. There are a lot more people involved too, and I think as problems involve more people and are more complex, they need to have more consideration. — Carlton

> You also have to consider society at large. If you're building a building, let's say, you want to make sure that the people that are occupying the building will be safe and secure in your building and that it's not going to collapse while everyone's in there. — Heather

As illustrated by these quotes, our participants conceived the value of empathy as an abstract tool to take responsibility and avoid causing harm to people. Felicia went as far as expressing that empathic approaches are taught in engineering due to the engineering mistakes that failed to consider people when designing:

> [Engineering mistakes] are something I learned in my engineering classes. Like, we learn about mistakes all the time and a how a lot of them are deadly because you're making planes or you're making bridges—or whatever —that collapse. So, I think [instructors are] trying to ingrain more empathic [approaches] because people in the past haven't been thinking of other people when they're making something. — Felicia

6.1.2. Align the design with the needs of specific users

Students also conveyed a belief that empathic approaches are valuable to align the design with the needs of specific users. By specific users, we mean the stakeholders who students considered as relevant for the design, such as the primary people that will use their project. Students' descriptions of considering specific users came after prompting them with the question of the role that empathic approaches played for their project. Hence, the focus of empathic approaches shifts from people broadly to more specific individuals whose perspectives were possible for participants to solicit during the design project. Felicia, who was part of a team in charge of designing a device that could allow people with lower limb amputation to row, explained the value of using empathic approaches for their project to provide an affordable solution:

> After talking to rowing people, it was pretty standard that a footplate is a few hundred bucks, like certain equipment that you use in the boat, it's a few hundred. So, if we can keep it up to par with that, we think people will be able to afford it. We didn't want to mess up their own prosthetic. So, the actual user was in mind with every decision; how it would affect them if we made that decision. So, I think, what we came up with was the best possible solution […] So, I think it's really important to remind people to think of the user in mind and put yourselves as much as possible in their position. — Felicia

In Anna's case, she explained that empathic approaches were valuable and more influential to align the design with the needs of their specific users because their project dealt more directly with the emotions of the drivers:

> I think as far as how we were designing our prototype, and all the different research we're doing in different industry fields, a lot of that was dealing with the emotions of a driver. So, I think for our project, [empathic approaches] probably had a little bit more influence in those day-to-day decisions. — Anna

Grace also described her expectation that understanding customer needs through empathic approaches is a part of a successful project:

> … you kinda really have to feel for the customers and understand their needs to have your project be correct. — Grace

6.2. Findings for RQ2: how students report behaving in ways that are considered empathic approaches

Overall, when our participants reported their behaviour during their capstone design projects, they reported considering a wide variety of stakeholders. Those stakeholders included people relevant to the project in terms of the design (e.g. project sponsor or potential users), which aligns with their espoused beliefs about the value of empathy in engineering design. However, participants also reported considering stakeholders in terms of their academic context (e.g. faculty advisors, teammates, themselves). Students ultimately reported prioritising the perspectives of those that impacted them as students when making decisions during their capstone design project, even at the expense of integrating what they learned from other perspectives, such as the users.

6.2.1. Students reported considering perspectives of design stakeholders

The stakeholders that students reported considering during their capstone design experiences included people or systems broadly (e.g. the environment), specific users (relevant to the design), and their company sponsors, advisors, and themselves as engineering students (relevant to their educational experience). For example, Brian described how his design team considered the environment and people (broadly) when deciding how to create bioplastic for an automotive company:

> I think [empathic approaches] played a role by us looking at how our product would affect the environment, other people, future generations. So, I think empathy played a pretty decent role because our end goal was to make this product that is going to be no environmental harm, no CO_2 emission, be able to be biodegradable. You're not going to see it out in the ocean floating around with a sea turtle eating it or something. — Brian

Students also described considering the perspectives of potential users for their specific design. Darcy, who was part of a team in charge of creating a device that would detect obstacles for powered wheelchair users, explained how her team considered the perspective of the user when deciding what type of detection to choose for their project:

> We were obviously thinking about the potential user and what that person would want … But, um, on deciding between doing collision detection and like doing potholes we thought that [collision detection] would be more useful because the user would benefit more and avoid more obstacles. — Darcy

6.2.2. Students reported considering and prioritising the perspectives that impact them as students

Another perspective that students reported considering for their design decisions was their own perspectives in terms of how they, as students, would be affected by the decision at stake. This reported behaviour emerged when participants described their consideration of project workload and grades. Not only did students consider their own perspectives, but they conveyed that they ultimately prioritised the perspectives of those that impacted them as students. As an example, when we asked James how empathic approaches played a role in their decision about which project to choose, he explained:

> Our advisor was more interested in the pressure ulcer project and we cared what our advisor thought because she gives us our grade. — James

Students made this prioritisation explicit as they plainly described their choices. For example, James described how his team did consider multiple perspectives, but ultimately prioritised the perspective of their faculty advisor:

> At the beginning, we met with a nurse halfway through the second semester and then, we realized, 'oh okay, so this [apparatus to determine pressure ulcer] is something that we could actually use and that other manufacturers actually haven't thought of yet or haven't gone through patents or whatever.' So, the pros were that. Since it's a really open topic, we could've submitted anything and passed [the class]. But another pro was our faculty member liked it a lot more. And the last pro is that it was just more interesting to the other group members and me because we didn't know as much on the topic. And, mainly because of the faculty member liking it more and it being more open ended and more interesting, those were the main reasons we chose to go with this pressure ulcer project instead of the door one. — James

Students also described their consideration of stakeholders being less important for their design decisions due to their difficulty of managing other demands on their time as students:

> Ideally you would want whatever prototype you're making to fit all of [the company sponsor's] specs but given the fact that we're undergraduate students we have other classes. This is only one class, which might be a major chunk of our time, but it's not all of it. It's difficult to realistically achieve everything, unless you're spending every waking moment dedicated to it. — Heather

Despite conveying a desire to prioritise the user, and despite feeling discomfort with the prioritisation of the perspectives that impacted them as students over the perspectives of users, Elfrieda went along with her team's desire to complete the capstone project:

> I think from the standpoint of my group, because they're getting to the point that like, 'I'm graduating in three weeks, I'm now more focused on my future employment than this project,' they're very much 'just let's get this done.' Whereas, I'm thinking more, 'what is the best solution that serves long-term as a design project?' — Elfrieda

> We haven't even been testing [the apparatus for powered wheelchairs to detect obstacles] on people who are wheelchair users. I mean, it's a little bit like, 'everybody call your friends because we need to test this on as many people as we can get in front of', which it kind of goes against everything I stand for, as the type of engineer that I am. But I also understand the constraints of, you know, this is a student project, everybody just wants to get to graduation, like, I understand where everyone else is coming from. — Elfrieda

6.3. Findings for RQ3: relationship between students' espoused beliefs and reported behaviour

This study makes a contribution by comparing the espoused beliefs and reported behaviour of engineering students from data collected based on a single capstone design experience for each participant. In order to make this contribution, it was first necessary to conduct the analysis and generate findings about students' espoused beliefs and reported behaviour individually, which were presented in the previous two sections. In sum, our data analysis and interpretation revealed that while students conveyed an espoused belief that empathic approaches are valuable to (1) protect people, (2) understand the needs of specific users, and (3) engage in the consideration of the perspectives of various stakeholders, their reported behaviour did not demonstrate the translation of what they learn from empathic approaches into their final design decision. Instead, students prioritised the perspectives of those in the academic setting that benefit them as students, which did not align with their espoused belief of the value in considering the perspectives of people and specific users. In other words, we answer our third and final research question by concluding that there is a disconnect between students' espoused beliefs and reported behaviour. Students describe the value of empathy and even report behaving in ways that includes considering multiple perspectives, which is encouraging. However, students ultimately report prioritising the perspectives that will help them accomplish their goals as students in an academic context. At the end of the day, we are concerned that there is little value in documenting that students espouse the value of empathy and go through the motions of taking multiple stakeholder perspectives when their design decisions are ultimately made so that they can complete the project in a timely fashion and with a desirable grade in place.

7. Discussion

Our findings suggest that students have difficulty in aligning their espoused beliefs about empathic approaches with their reported behaviours in capstone design projects, and specifically in their design decisions. As we argued in the Background, the model by Walther, Miller, and Sochacka (2017) proposes that for engineers to embody empathy, three intertwined dimensions need to be developed concurrently: empathy as a professional way of *being*, empathy as a teachable and learnable *skill*, and empathy as a practice *orientation*. We relate our findings to the *orientation* dimension to theorise about the misalignment between students' espoused beliefs (e.g. empathy is valuable to consider people broadly) and their reported behaviour (e.g. considering and prioritising stakeholders). The *orientation* dimension is defined as the 'mental dispositions that influence how engineers and engineering students engage in practice situation' (Walther, Miller, and Sochacka 2017, 133). We specifically connect our findings to two components in the orientation dimension – micro to macro focus and epistemological openness – and posit that developing these components can serve as a possible gateway for students to embody empathy in engineering design contexts.

The disconnect between students espoused beliefs and their reported behaviour provides further evidence for the concurrent development of students' *skills*, *orientation*, and ways of *being* to embody empathic approaches when making design decisions. Scholars have provided educational tools on how to teach empathy in engineering, such as guidelines on stepping in and out of users' perspective or frameworks on affective and cognitive processes to take others' perspectives (Fila and Hess 2015; Hess and Fila 2016; Kouprie and Visser 2009). However, a focus on just developing students' empathic skills is limited because students' beliefs about who engineers are (being) and what role engineers play in society (orientation) also have implications for how students embody empathy in engineering (Walther et al. 2020; Walther, Miller, and Sochacka 2017). For example, prior work that examined media portrayals of engineering (Sochacka et al. 2014) found that engineering is mainly presented as using math and science to problem-solve, which can create in students a cognitive dissonance when learning about the importance of empathic skills in engineering (Walther et al. 2020). This cognitive dissonance can cause students to be conflicted about how to *be* engineers because empathy is not objective, logical, or rational and, therefore, not considered engineering work (Fila and Hess 2016; Walther et al. 2020). Because of the beliefs that students hold about who engineers are and what they need to do in a given situation, even when they learn about considering others when designing, they might still end up choosing to provide a technical-centered solution rather than a solution that fits the needs of others (von Unold et al. 2018). In other words, students' *orientation* (engagement and behaviour in practice) is compromised by their *being* (beliefs and assumptions), even though they have acquired the empathic *skills* to consider others.

Our findings suggest that engineering education needs to consider students' *orientation* when teaching empathy, primarily highlighting the development of the micro to macro focus and epistemological openness. First, micro to macro focus plays an important role when embodying empathy because it allows students to consider the diverse and broad stakeholders that are directly and indirectly affected by engineering design decisions. Micro- or mezzo-level encompass considering individuals/specific users (micro) and groups of people (mezzo), whereas macro-level encompasses the engineering profession's consideration of the impact of the field on society (Herkert 2005). Walther and colleagues acknowledged that the engineering profession must develop a broader values commitment that addresses 'power, inequality, and the often-inequitable distribution of the risks and benefits of engineering work along the micro to macro spectrum' (Walther, Miller, and Sochacka 2017, 138). Without a macro-level of understanding, students risk seeing empathy as only applicable in design decisions that directly affect users (e.g. bridges or buildings) without considering how other, indirect decisions still affect society at large. In our findings, designs, projects, and fields that directly impact individuals (micro) or groups of people (mezzo) allowed students to believe that empathic approaches are needed. For example, Anna, who was part of a biomedical engineering project, mentioned, 'I think our project had maybe more empathic [approaches] than most … '. Grace, who mentioned that she wanted to pursue a career towards customer services, also said, 'because of the career I'm going into … , you kinda really have to,' which does not acknowledge how empathy plays a broader role to support consideration of the impact of engineering decisions at the societal level. Previous studies in engineering have already found that the recognition of empathy is sometimes perceived as an add-on (Strobel et al. 2013), depending on the 'scope' of the project (Fila and Hess 2016) or sometimes not even counted as part of problem solving (Brewer et al. 2017). The belief that empathy is only relevant in certain contexts can establish risk where students constrain the impact of their decisions to the macro-level. Therefore, we propose that to support students' empathic embodiment in engineering, it is essential to guide their day-to-day design decisions in class with a micro to macro focus (Walther, Miller, and Sochacka 2017) on the impacts of the engineering profession on users, people, and society.

Second, addressing epistemological openness can allow students to close the gap between their beliefs and behaviour about empathy by considering, understanding, and valuing the inclusion of diverse perspectives during the decision-making process (Walther, Miller, and Sochacka 2017). Epistemological openness emphasises that there is an equal value in the 'subjective experiences and perspectives of others' (Walther, Miller, and Sochacka 2017, 135) as there is in technical knowledge. However, students' technical rationality (Schon 1984) learned from their classes might prevent them from perceiving engineering design as a complex and messy process that requires diverse input into the decision-making process. In fact, the culture of engineering is often depicted as being a technical field with no relation to social or political issues (Cech 2013). At the end of the day, this cultural reality of the engineering field affects how students consider, understand, and value the inclusion of diverse perspectives because these messages shape students' understanding of what is valuable when making design decisions. Within our study, we found that students tended to prioritise their positionality as students, implying that including and translating the perspectives of other stakeholders into their design was of less value than their own. For example, a student expressed that when choosing between detecting the steepness of a hill or detecting potholes, they decided to go with pothole detection because they 'were kind of running out of time' and 'already knew that [it would] work.' However, from the student's transcript, we learned that this decision failed to account for the perspective of the user they interviewed who expressed the importance of detecting the steepness of hills. Therefore, it is important to develop students' epistemological openness, encouraging them to value and prioritise the perspectives of diverse stakeholders, and how stakeholders can also contribute to developing a meaningful product.

8. Recommendations

Capstone design can provide a unique design experience for undergraduate students to work with ill-structured problems and, therefore, can serve as a key platform to encourage engineering students to embody empathic approaches when making design decisions. In this section, we connect our findings to recommendations for (1) undergraduate programs broadly, (2) engineering educators who teach design, and (3) scholars in the field of engineering education research.

On an undergraduate program level, engineering programs must acknowledge the value of empathy in engineering broadly and in capstone design. Empathy is embedded in ABET criteria, and a lot of programs do put effort into developing empathy as a professional competency in engineering students. However, this study points to a limitation in that engineering curricula more commonly teaches at the micro-level focus (Bielefeldt et al. 2016), rather than also considering the macro-level understanding that is necessary to consider broader stakeholders when making design decisions, and even switching between levels. For example, based on the finding that students broadly understand empathy as needed to avoid causing harm to people, we recognise the limitations of checking off the 'ethics box' through presentations of ethical dilemmas alone, which often happens in first-year introductory, capstone designs, or stand-alone ethics courses. Curriculum designers can reflect on the extent to which micro to macro focus is developed in students and how students consider direct and indirect stakeholders on their day-to-day design decisions. We recommend that faculty with control of the curricula and/or programming consider including the development and scaffolding of empathic approaches in ways that go beyond illustrating engineers' responsibility to avoid causing harm to people. Faculty can consider including elements that highlight the history of the field, links to social justice, and broader global implications to provide a platform for deep reflection on how empathic approaches are necessary in the field.

Within the classroom, educators who teach engineering design can provide stakeholders with the opportunity to speak and shape the decision-making process of designers, which has already been acknowledged as a way to create relevant and contextual design solutions (Sanders and Simons

2009). Thus, instructors can promote the involvement of diverse perspectives by allowing users to provide feedback that impacts the grading system or inviting the stakeholders to grade the final design (for rubric examples, see Cantwell 2018; Gallagher and Thordarson 2019). A rubric could also be co-created with the stakeholders and the students, which can represent the involvement of multiple perspectives during development of the assessment. The integration of these perspectives will challenge students to seek to empathically understand others and include those voices in decision making (Zoltowski, Oakes, and Cardella 2012). Beyond the development and accountability of empathic skills in engineering programs, educators also should consider how to allow students to embody empathy in engineering. For example, Walther, Miller, and Sochacka (2017) suggested that adding reflection to courses can widen the opportunities for students to develop 'reflexive value awareness' in alignment with the orientation dimension. Beyond explicit inclusion in the curricula, engineering educators must be aware of how to teach empathic approaches to students in capstone courses. As the value of empathy in engineering contexts has only recently been articulated and is continuing to emerge, instructors must learn the core concepts of empathy in engineering themselves, revisit assessments, and reflect on ways to integrate these concepts into the classroom (see for example, Sochacka et al. 2020). With this awareness instructors will be more capable of holding their students accountable for micro to macro focus, epistemological openness, and other constructs valuable for empathy development. As shown in this research, just teaching the skills does not help students to embody empathy in engineering, therefore our recommendation is to also find ways to close the gap between beliefs and enacted behaviours within this context.

For engineering education researchers, this investigation opens opportunities for further study. While the value of empathy in engineering has been established, empirical and theoretical studies are needed to extend knowledge of how to further integrate empathy as a core construct in engineering. More specifically, as shown in this investigation, additional research can support closing the gap between espoused and enacted behaviours in students and engineers. Researchers can study the role that instructors play when teaching empathic approaches in engineering and the implications of their pedagogical strategies on students' development of empathy.

9. Conclusion

Empathy is needed in engineering, and tools to teach engineering students about empathic approaches for engineering design decisions exist (Sochacka et al. 2020). However, just developing students' empathic skills is not enough for students to embody empathy in engineering. Through this study, we explored (1) engineering capstone students' espoused beliefs about the value of empathic approaches for engineering design decisions, (2) students' reported behaviour of who they considered and prioritised for their design decisions, and (3) the relationship between their espoused beliefs and reported behaviour. This study revealed that while students espoused a belief that empathic approaches are valuable to consider implications of decisions on people, their reported behaviour did not demonstrate a translation of empathic approaches into their design decisions. Instead, students prioritised the perspectives of those within the academic setting and that benefited them as students. Based on these findings, we recommend engineering educators consider how to teach empathy beyond the skill development and start addressing the beliefs that students hold about who engineers are and how they are supposed to make engineering decisions.

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Appendices

Appendix 1. Interview protocol

We are interested in hearing about a decision that occurred when (1) ***you needed to make an explicit choice between multiple possible options****, and (2)* ***the choice had implications or mattered to your project***.

1. As an engineering design team, you have gone through the design process, which included a lot of decision making. Thinking about your experience …
   a. What was an important decision you had to make? What were the alternatives? What did you choose and why?
   b. What was the timeline like?
   c. Who was involved?
   d. How did you reason through the decision? Why? Pros? Cons?
   e. How did you feel about the decision once you made it? Tell me about an important decision that you've made recently in your life. What were the alternatives? What did you choose and why?
2. There are different ways to reason through decisions. I'm going to ask you to talk about the decisions you just described with respect to three distinct aspects of human reasoning: rational, intuitive, empathy.
   a. First, rational. This type is deliberate, uses logic to weigh pros and cons, often impersonal. What role did rational reasoning play?
   b. Second, intuitive. This is an immediate reaction to one of the options, gut-feeling, and is not easy to explain. What role did intuitive reasoning play?
   c. Finally, empathy. This type of reasoning considers the decision from another person's perspective. What role did empathic reasoning play?
3. Overall, how do you think engineering decisions should be made? Why do you think that? Where does that belief come from?
4. So far, what has engineering education taught you about how to make engineering decisions?

Appendix 2. Targeted questions for data condensation

1. How do students report using empathic approaches for their design decisions?
2. How do students describe empathic approaches as valuable in engineering design decisions?
3. Whose perspectives do students describe considering during their design project?
4. Whose perspectives do students prioritise when making design decisions?

Appendix 3. Example of codebook

	How are these students describing the role of empathic approaches when making decisions?			
	How do students report using empathic approaches?	Line #	How do students describe empathic approaches as valuable?	Line #
Anna	She doesn't describe how she uses empathy. She says the importance but doesn't describe it		Outside of her project: She thinks it is important when dealing with people's emotions. Especially in medical field.	425–430
			To design things better for the user	467;
			To justify their decision to people w/ sponsors	372–374; 376–380;

	Who are students taking into consideration when making decisions during their design process?			
	Who are students considering?	Line #	Who are they prioritising? Why?	Line #
Anna	Sponsor/Industry	27; 82–83;	Themselves, their schedule, get it done	371–374
	Project Advisor	29; 76–77		
	Capstone Professor	78		
	Person/driver	322; 426; 38–42;		
	Themselves/self-interest	30–33; 344		
	Other people (general)	408		