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ARTICLE

A qualitative study of how mental models impact engineering students' engagement with empathic communication exercises

Nicola W. Sochacka, Kathryn M. Youngblood, Joachim Walther and Shari E. Miller

College of Engineering, University of Georgia, Athens, GA, USA

ABSTRACT
Empathy is an important professional skill for engineers. Defined as the capacity to understand and share the feelings of others, empathy can help engineers work on teams and interact more effectively with clients. Approaches designed to teach empathy to engineering students, however, are limited, as are studies on such interventions. This study investigated two research questions: What mental models about engineering and engineering relationships do students bring with them into engineering classrooms? And, how do these mental models impact students' engagement with and understanding of empathic communication exercises? Data for the study included student reflections from second-year mechanical engineering students (n = 36 x 4 reflections each, one for each of the four empathic communication modules). The findings comprised five themes from a cross-section of the data at one point in the semester and narrative trajectories that capture the experiences of two students across all four modules. The findings suggest that learning about empathy in engineering can call into question the mental models students bring with them about what engineering is and what engineers do. Instructors need to be aware of the challenges associated with confronting these pre-existing understandings and attend to them in the design, implementation, and assessment of empathy-related activities.

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Empathy; professional skills; mental models; constructivist theories of learning; teamwork; design

1. Introduction

Numerous studies of engineering practice have provided compelling evidence of the profession's socio-technical nature and, therefore, the need for a greater focus in engineering curricula on professional skills and orientations (Bucciarelli 1994; Jonassen, Strobel, and Lee 2006; Stappenbelt 2010; Trevelyan 2007). Compared to other professional skills, however, such as leadership and teamwork (Shuman, Besterfield-Sacre, and McGourty 2005), the development of empathy in engineering undergraduate programmes has received limited attention.

Empathy, loosely defined as the capacity to understand and share the feelings of others and adequately respond to them (Sochacka, Walther, and Miller 2018), is important to engineering for multiple reasons. According to a recent study conducted by Google (Duhigg 2016), the teams they examined that performed best in their company were those that had a high level of psychological safety, which is comprised of two behaviours, conversational turn-taking and empathy. The Australian Council of Engineering Deans (ACED) concurs with this finding. In their recent scoping study for Engineering Futures 2035, they stated that:

> The AICD [Australian Institute of Company Directors] view is that specialists will be working increasingly in cross-functional teams and higher order soft skills such as empathy, professional ethics and emotional judgment are likely to be increasingly valued (Crosthwaite 2019, 27).

Empathy is also crucial in the context of service learning and humanitarian engineering, particularly when engineers from Western environments engage with resource-constrained communities (Birzer and Hamilton 2019). Furthermore, empathy is a tool for creative thinking (Root-Bernstein and Root-Bernstein 1999), which is particularly important for engineering design. Empathy has also been described as one of six senses that are needed to succeed in the Conceptual Age (Pink 2005).

In this study, we examined student reactions to a pedagogical development (a set of four 75-minute modules) designed to introduce engineering students to empathic communication techniques. Our findings point to the need to employ a constructivist view (Mayer 1983; Merrill 1991) when teaching empathy to engineering students. More specifically, we emphasise the need to attend to students' pre-existing 'mental models' (Mayer 1983, 143) about what constitutes engineering knowledge and practice. This perspective on teaching and learning is succinctly articulated by the United States' National Research Council (2000):

> A logical extension of the view that new knowledge must be constructed from existing knowledge is that teachers need to pay attention to the incomplete understandings, the false beliefs, and the naive

CONTACT Nicola W. Sochacka sochacka@uga.edu University of Georgia, Athens, GA, USA

> renditions of concepts that learners bring with them to a given subject. Teachers then need to build on these ideas in ways that help each student achieve a more mature understanding. If students' initial ideas and beliefs are ignored, the understandings that they develop can be very different from what the teacher intends.

In line with this understanding, we emphasise that teaching empathic communication techniques is not a simple matter of adding an objective set of skills to students' tool kits. Rather, we highlight a range of potential tensions and synergies that may influence how students incorporate such training into their developing understandings of what constitutes engineering knowledge and practice.

2. Relevant prior work

Prior efforts to integrate empathy into undergraduate engineering programmes have varied in their goals and associated activities (for an extended discussion of contexts and techniques for developing empathy in engineering, see Hess and Fila 2016). Many of these initiatives productively build on prior work in empathic design (e.g., Stanford d.school 2019) and focus on how to connect student engineers with users and product contexts (Bell-Huff and Morano 2017; Burns and Lesseig 2017; Gray et al. 2015; Mitchell and Light 2018; von Unold et al. 2018). Gray et al. (2015), for example, revised and expanded an existing method, the cognitive walkthrough, to encourage engineering students to take on the role of users and 'talk through' (Gray et al. 2015, 5) their experiences with a proposed product or system. Gray et al.'s method, which they renamed the empathic walkthrough, provides students with a new perspective on the design space through 'revealing tacit assumptions they have about the user they are designing for, and externalizing these assumptions by walking through the use of the product or system' (Gray et al. 2015, 5). In a similar vein Mitchell and Light (2018), in collaboration with first-year engineering students at their institution, developed a series of 'user empathy experiences' intended to help bridge the gap between imagining and feeling by having the students participate in fun, challenging, and unique activities designed to mimic what a user would experience in his or her own environment. Some of the experiences they have co-developed to date include becoming a wheelchair user in Africa, a bomb-diffusion team trekking across a landmine-ridden field in Cambodia, and an environmentalist attempting to remove vast amounts of debris from the ocean.

Immersive design experiences offer another rich context in which to explore and support the development of engineering students' empathic sensibilities. In a phenomenography examining how students experience and understand human-centred design, Zoltowski, Oakes, and Cardella (2012) found that students must overcome a threshold to move from understanding design as technology-centred to design as human-centred. They noted that 'immersive experiences involving real clients and users were critical in allowing the students to experience human-centered design in more comprehensive ways' (Zoltowski, Oakes, and Cardella 2012, 28). Among the qualitatively different ways of understanding human-centred design, Zoltowski, Oakes, and Cardella (2012) identified empathic design as the most comprehensive understanding, citing the 'strength of the connection with the users and the breadth and depth of the understanding of the context' (p. 46) as differentiating factors. They found that students who practiced empathic design sought to have a holistic understanding of stakeholders – their personal motivations and dreams as well as their cultural and political surroundings – through forming a strong connection with end users, rather than relying on preconceived ideas and assumptions.

In parallel to efforts focused on empathy in design settings, an increasing number of studies are also examining how empathy can contribute to the complex processes involved in teaching and learning engineering ethics (Gray et al. 2016; Hess et al. 2017; Hess, Strobel, and Brightman 2017; Hoople and Choi-Fitzpatrick 2017; James et al. 2018). Hess, Strobel, and Brightman (2017), for instance, studied the development of empathetic perspective taking, defined as considering the perspectives of those not present and incorporating them into the reasoning process, as a critical part of ethical decision-making. The context for their qualitative study was a graduate-level course in which students explored in-depth case studies and were engaged in stakeholder perspective-taking exercises, online and in-class discussions, and reflection writings. Using critical incident techniques, Hess et al. identified potential causes of changes in empathetic perspective-taking abilities, as well as the nature of these changes. Their work found the strongest relationship between sharing differing perspectives and developing open-mindedness. Participating in role-play exercises, where students enacted different stakeholders, was also noted as a cause of increased open-mindedness (Hess, Strobel, and Brightman 2017). With a similar focus on leveraging different perspectives to surface and work through ethical questions, research conducted by Gray et al. (2016) and Hoople and Choi-Fitzpatrick (2017) points to the potential for transdisciplinary settings, which expose students to different disciplinary perspectives, to support ethical discussion making. As stated by Gray et al. (2016, 2), '[W]e want the students to understand how using alternative disciplinary frameworks changes their understanding of problems.'

While our flexible approach to teaching empathy to engineering students shares some features with the above-described efforts, it is distinct in the following three ways. First, we view empathy as a professional skill that not only facilitates better engineering design outcomes but also better relationships with the full range of people and environments that engineers come in contact with every day (e.g., our technical peers, bosses, partners from other disciplines, clients, contractors, and members of the many diverse stakeholder groups that make up 'the public'; National Society of Professional Engineers, 2019). This perspective on empathy broadens the scope for skill development beyond designer-user interactions. Second, our approach draws on theoretical frameworks and long-standing pedagogical techniques from the field of social work, a discipline that conceptualises empathy as an essential skill and orientation of its practitioners. More specifically, this disciplinary perspective has infused into our work a focus on recognising the importance of the Self as the primary tool in all interactions with other people (Walther, Miller, and Sochacka 2017), the value of approaching others with empathy, warmth, and genuineness (Walther, Miller, and Sochacka 2017), and how empathy can inspire action towards social justice (Segal 2011). Finally, our approach leverages emerging insights from the neurosciences, which highlight mutually antagonistic relationships between empathic and analytical thinking and the need to consciously recognise and switch between these cognitive modes (Battarbee, Fulton Suri, & Gibbs Howard, 2014; Jack et al. 2013). We have discussed these distinguishing features of our approach to conceptualising and teaching empathy in engineering elsewhere (Walther, Miller, and Sochacka 2016, 2017). In one of these prior works (Walther, Miller, and Sochacka 2017), we synthesised these insights into a context-specific theory of empathy in engineering, illustrated in Figure 1.

In this model, we define empathy as a skill, a practice orientation, and way of being. The pedagogical approach we describe below is designed to provide opportunities for students to engage with all three dimensions of empathy illustrated in the model.

3. Overview of the empathy modules

Our pedagogical innovation entails a series of four empathy modules, which are integrated into an engineering and society course that is mandatory for all sophomore mechanical engineering students at our institution (for more details on these modules we refer readers to Walther et al. 2016). As illustrated in Figure 2, each of the four modules is grounded in a particular set of empathic communication skills (see Figure 1), which progressively build on one another.

For example, in the first module, students are guided through activities that involve encountering others. In

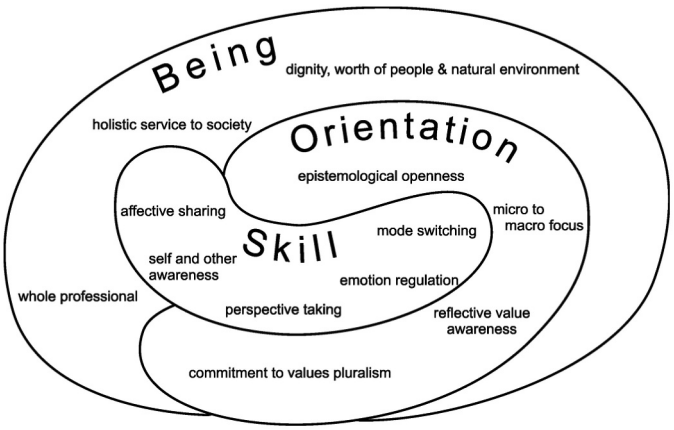

Figure 1. A Model of Empathy in Engineering (Walther, Miller, and Sochacka 2017, 133).

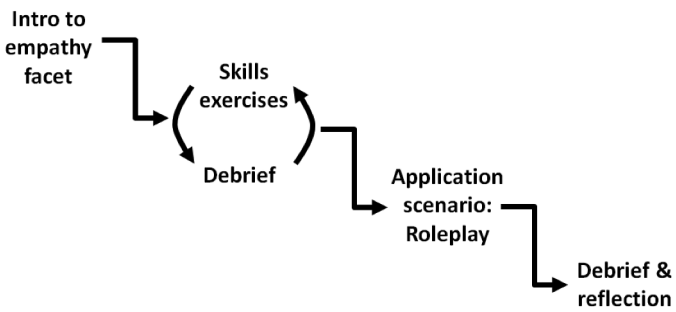

Figure 2. Overview of the sequence of the four empathic communication modules.

these interactions, students are encouraged to develop an awareness of how they use their Selves (their body, voice, etc.) as the primary tool for building relationships with others. These skills form the foundation for later modules, which focus on recognising and productively regulating emotions that arise in empathic exchanges, affective responding, and mode-switching.

Each module follows the same structure (see Figure 3). First, modules are introduced to students and key concepts are defined and described. Second, students are invited to participate in skill-building activities and reflect on those activities in small groups, and then collectively as a class. Third, students are given an opportunity to practice the skills they have just learned in a real-world engineering context through role play. These role plays vary from year to year and across instructors. Some settings that we have previously used include the Flint Water Crisis, the North Dakota Access Pipeline, and the Pacific Gas and Electric (PG&E) power blackouts. Finally, the class debriefs together and students are given a prompt to reflect on their experiences.

The reflection prompts for the first three modules ask students to think back through the module and discuss moments of enjoyment or discomfort and reflect on the role of empathy in engineering. The reflection prompt for Module 4 is designed according to Walther, Sochacka, and Kellam's (2011) emotional indicator approach. Examples of both types of prompts are given in Table 1.

4. Methods

This study examined the following two research questions: What mental models about engineering and engineering relationships do students bring with them into engineering classrooms? And, how do these mental models impact students' engagement with and understanding of empathic communication exercises?

Data for the study included the sophomore mechanical engineering students' empathy module reflections for the Spring 2016 (n = 36) semester (1 per student per module). The research team obtained ethical approval to collect and analyse these data. These data were imported into NVivo 11, a qualitative data analysis software package, and analysed using thematic analysis techniques (Aronson 1995).

Data analysis was conducted primarily by the second author and included the following steps. First, Youngblood read through the data to identify themes pointing to mental models that students brought with them to the classroom about engineering, such as the importance of communicating engineering processes and results to the general public. In parallel, she identified instances where these pre-existing understandings seemed to impact how students engaged with the empathic communication exercises. These steps resulted in two lists of codes with attached memos that described how certain pre-existing understandings impacted student engagement. As Youngblood developed and refined these lists, the research team met weekly to review the codes and relationships between them. In these meetings, the team also explored connections between the codes and the theory of empathy in engineering presented above and potential pragmatic implications of the findings for teaching empathy to engineering students (see pragmatic validation in handling data in

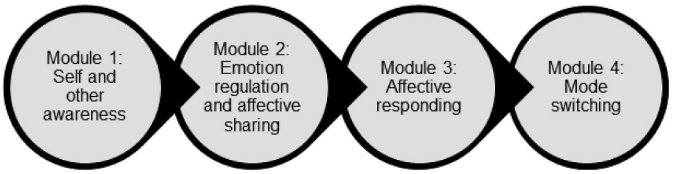

Figure 3. Structure of each of the four empathic communication modules.

Table 1. Examples of reflection prompts.

Reflection prompt for Module 3	Reflection prompt for Module 4
Think back through yesterday's module on **affective responding**. 1. How did these activities challenge and/or align with the ways that you think about yourself becoming an engineer? 2. Which parts of the exercises did you find particularly challenging/ uncomfortable/useful/ [insert your other reactions here…]? You are not limited to just answering these questions in your reflection. Please include any other thoughts you think are important. Submit your reflection (about two pages) as a PDF file on eLC.	Read through the following statements and think of specific incidents they bring to mind. You don't have to directly or specifically answer the statements. • There was a moment during today's module when I started to realise that … • During today's module, I struggled to get my head around … • When my partner responded analytically to my story, I was surprised to feel that … • When my partner responded empathically to my story, I was surprised to feel that … • As the engineer/stakeholder in the role play, I suddenly understood how … Submit your reflection (about two pages) as a PDF file on eLC.

Walther, Sochacka, and Kellam 2013). The latter consideration led the research team to organise the findings into two analytic views – a cross-section of the data that showed a range of what the research team judged to be lower-to-higher engagement with the modules, and two narrative trajectories that illustrated the complex nature of students' experiences across all four modules. These two views on the data were selected to illustrate for instructors the potential range of responses that students might have to the empathic communication exercises.

The different positionalities of the research team members impacted the analysis and development of the research findings. As an undergraduate student, Youngblood had experienced the modules in an earlier course taught by Walther. Before beginning to analyse the data, she also assisted Sochacka in facilitating the modules to mechanical engineering students whose reflections she later analysed. These experiences provided Youngblood with unique insight into the data and into what kind of information might benefit instructors who desire to teach such skills. In this study, Walther and Sochacka were similarly focused on how the findings could advance knowledge related to teaching empathic communication skills to engineering students. For a related analysis that focuses less on instructional aspects and more on how engaging with empathy provides insight into engineering students' professional formation, we refer readers to Walther et al. (2020).

5. Results

The following sections provide two analytic views on students' experiences. First, we present five themes that form a cross-section of the data at a particular point in the semester that revealed the *variation* among students' experiences. Second, we present narrative trajectories that capture the experiences of two students throughout the semester, thus providing a sense of the *developmental dynamics* observed.

5.1. Diverse ways of understanding the role of empathy in engineering

The five themes described here derived from a thematic analysis (Aronson 1995) of student reflections following the third in the four-module sequence. At this point in the semester, students had already engaged with the empathy exercises in the first two modules and they were in their individual, dynamic processes of sense-making, as illustrated in the variation in student understandings detailed below.

In the third empathic communication module, students are asked to explore two concrete skills that contribute to affective responding: *attending*, utilising body language to attend to the speaker to convey genuine interest, and *reflecting*, i.e., reiterating thoughts ('If I'm hearing you right, you said that … ?'; also called paraphrasing) and identifying emotions expressed by a speaker to convey attentiveness and affirm the validity of the speaker's words ('so, you were frustrated when … ?'). These skills were practiced first in pairs and then in a role-play setting involving an engineer communicating with stakeholders about a community project (for more detailed information on the modules, see Sochacka et al. 2020).

These themes are organised in order of what the research team deemed to be increasingly sophisticated forms of engagement with the empathic communication exercises. The themes also reflect increasing engagement with the empathy in engineering model's three dimensions shown in Figure 1. We discuss one example quote to illustrate each theme.

Theme 1: Not engaging with the exercise – "it's awkward"

"I felt as if responding with how the person is feeling is very sarcastic toward the speaker … it felt as if we were talking to a therapist, very unnatural and one sided."

This student described acknowledging the emotional state of the speaker as uncomfortable and disingenuous – like 'talking to a therapist' – and rejected the value of such communication in engineering. We note the role of context in this discomfort – reflecting feeling is a common colloquial empathic technique, e.g., 'no wonder you were angry' or 'I would've been upset too.' In an engineering setting, however (i.e., the classroom and role play), this technique made the student feel awkward. This finding suggests that feelings have been excluded from the domain of engineering (Leyva, Massa, and Battey 2016) such that it is difficult for some students to engage with affective sharing or responding in this context. Put another way, acknowledging feelings (see 'affective sharing' and 'perspective taking' in Figure 1) does not seem to be part of some students' mental models of engineering communication. As a result, students who reacted in this way resisted engaging with the module.

Theme 2: Communication is key

"Public speaking is an essential part of engineering especially since a lot of our calculations are not understood by everyone therefore we must communicate our results to the general public."

This example highlights two common perceptions of empathy held by student participants. The first is that empathy is synonymous with the ability to communicate; this tendency to conflate empathy with communication is perhaps partially fostered by the design of the modules, which focus primarily on the skills dimension of empathy applied to professional practice (see Figure 1). The student here is expressing

developing insights into empathy, such as the importance of clear communication to foster mutual understanding among people of diverse educational backgrounds. However, there is also a clear sense of expertise intrinsic to the identity of the engineer. The relationship between the engineer and the public is depicted as one-sided, a method for the transfer of knowledge from the more educated party to the other (Robbins 2007). This mental model lacks a recognition of the value that can be gained by the engineer from listening to the public; it lacks the empathy to value perspectives beyond technical expertise (see 'epistemological openness' in the 'orientation' dimension in Figure 1).

Theme 3: Learning to listen

"As an engineer, this activity made me realize how important listening can be. Engineers are required to communicate well, and this means more than just working around problems … With attentive listening, responses come naturally, and in the future I will try to be a better listener rather than just a problem solver."

This excerpt shows insight into the utility of empathic skills, notably active listening. The exercises in the third empathic communication module seem not only to have fostered these skills' development but also led to an arguably more comprehensive understanding of what it means it be an engineer. The student articulates that an engineer should use communication to collaborate with others and not just to explain their own opinions. Listening is conceptualised as part of the engineering process, rather than just a means for problem solving or educating the general public (Leydens and Lucena 2009). This recognition of listening's importance is a fundamental reframing of the perception of stakeholders as potential partners in engineering design processes. Robbins (2007) described this relationship as 'public/expert dialogue and agreement' (p. 108).

Theme 4: Applied Skills

"… the paraphrasing part, especially, somewhat actually annoyed me a little … It just did not feel quite right … [The role play] gave me a clearer image of how engineers have to deal with situations like this in reality … As the engineer here, it was important to approach emotional stakeholders with intentions of understanding their side and getting to see things through their perspective."

This reflection speaks to the interplay of the facets of empathy as both a set of skills and a practice orientation (see Figure 1). At first, the student finds practicing empathic communication skills (specifically paraphrasing what the speaker had said to demonstrate active listening) 'annoying.' Taking this skill out of an applied context, a pedagogical feature that is arguably present in most technical engineering fundamentals courses, led the student to question its place in the classroom. However, in a role play designed to contextualise interactions within engineering practice, the student found the techniques to be useful and, in fact, critical to developing a working relationship with stakeholders. The student moved from a skill-based rejection of empathy to recognising the utility of empathy in practice. It is worthwhile to note that, in prior reflections, this student had written about understanding the skills of empathy in conversation; their reflection here shows a shift in conceptualising empathy not just as a set of conversational techniques but as both a mindset and a skillset with which to approach diverse stakeholders in an engineering setting.

Theme 5: Empathy as a Way of Being

"First, I must state that I no longer wish to become an engineer … I have long battled with choosing the correct major and field for me in which I can both excel at what I love and also help others … this empathic communication module allowed me to do one thing out of those two: help others by enhancing the community. This factor completely aligned with future goals for myself as a whole, and not just as an engineer."

This excerpt demonstrates another notable interplay between two aspects of the empathy model, in this case empathy as a practice orientation and as a way of being. This student wholeheartedly embraces the concept of empathy as a way of being; it is central to her vision of her life and her career (see 'whole professional' in Figure 1). Interestingly, her exposure to engineering thus far as a second-year student seems to indicate that empathy does not have a place within the practice orientation of engineering, leading her to change her major to find a more empathically-oriented career. This student's experiences in engineering education have led her to believe there is not adequate space for her empathic self, which prioritises helping others, to exist alongside, or as a part of, her professional identity as an engineer. Other studies have similarly identified a desire to help others as a reason for why some students, especially students from minority groups, leave engineering (Rulifson and Bielefeldt 2017; Seymour and Hewitt 1997). We note that this reflection comes from one of four female students in the class of 36, and suggests that there may be gendered differences in how engineering students respond to empathy-focused teaching innovations (Jacobs et al. 2016). A systematic study of gendered trends is beyond the scope of this article but offers a promising opportunity for future work.

5.2. Two student trajectories through the four modules

The above exploration of responses to a single module provides some indication of the variation of the impacts that students' different mental models of engineering have on how students respond to empathic

communication exercises. In addition to this analysis, we also found it valuable to examine the chronological trajectory of two students across all four of the modules, which were purposefully sequenced to build on each other and allow for a continuing exploration of empathy as a set of skills, a practice orientation, and way of being.

In spite of this purposeful sequencing of the four empathy modules, the data analysis showed that most students did not experience a linear growth in their understandings of empathy. Instead, we observed a complex interplay between the skill-building activities and discussions prompted by the modules, personal experiences with empathy, and prior mental models of the engineer's role fostered in engineering education.

The first set of reflections, though non-linear in nature, does seem to indicate evidence of deeper, more critical thought about the role of empathy in engineering. This type of non-linear trajectory was the most common across the data. Note that the numbers in the list correspond to reflections from one student, in this case a male, for each of the four modules.

1. '*We started by* . . . [trying] *to find some things we had in common with that person* . . . *Engineers tend to be goal focused analytical people, so* . . . *nearly everyone probably had figured that they had five minutes per person* . . . *I just saw it as an opportunity to talk to three people I didn't know. I think my approach led to a little discomfort in the conversation. I carried on too long* . . . *and even joked about overly obvious similarities like gender and major* . . . *I probably haven't sold myself as a very good group member or study buddy* . . . '

2. ' . . . *in reality I think it is far more important to maximise where grant money is going and find plausible solutions. How a stakeholder feels is kind of insignificant when you are discussing starving children. I think as a professional engineer I want to learn my trade well before I directly interact with stakeholder* . . . .'

3. '*I don't think I will work in a field that will put me in the same situation as the engineer here, but, as we saw in the* [class] *reading, a good engineer seeks a relationship with the community regardless.*'

4. '*When my partner responded to my story analytically I felt like he was less worried about me* . . . *I was able to see how a person who felt very strongly about a situation could take offence to an overly analytical response, because it almost turns them into a variable in a problem.*'

This student's reflection from Module 1 shows a strong disposition to regard engineering as a purely analytical endeavour (Cech 2014; Leyva, Massa, and Battey 2016). While the student self-identifies as a sociable person, he feels that skill does not have a place within an engineering classroom; rather, he worries he may have presented himself as too jovial in front of his 'goal-oriented peers.' This relaxed mindset stands in interesting contrast with the thoughts presented about Module 2. Here, the student's foundational perspective of the engineer as the expert emerges as he characterises stakeholder emotions as insignificant in the face of solving significant problems. This developing engineer hopes to avoid interacting with stakeholders directly until he has perfected his craft; it is thereby evident that he does not view empathic engagement with stakeholders as a fundamental part of the engineering process.

Again in Module 3, without the direct pressure of solving a problem, the student reiterates the importance of a community relationship, an idea likely influenced by the course readings (e.g., Robbins 2007). There is still some degree of removal from directly encountering the issue of empathy in engineering as the student believes he will not face a situation involving an emotional stakeholder in his profession. After the Module 4 role play, however, the student recognises that although it is not necessarily his preferred communication method, the skills of empathic communication (versus an analytical response) can be extremely relevant in tense stakeholder situations.

This trajectory shows a highly non-linear journey through the modules. These reflections are particularly poignant in the struggle between the professional identity as an engineer and the student's personal identity; the contrast between his view of himself as an amicable person and his view of an engineer as a superior problem solver remains unresolved throughout the reflections. Even in later modules, it is evident that many of the student's preconceived ideas about the engineer as the expert and his questions about the true relevance of empathic skills within engineering practice remain. However, through the contrasting thoughts presented in his reflections, sometimes contained within the same reflection, it is evident that the student is attempting to incorporate this new understanding of empathy into his pre-existing, mental models of engineers, and that this deepening understanding of empathy is subsequently pushing back against such mental models. The juxtaposition of these cornerstones of professional identity formations were common in the students we studied. We suspect that a student such as the one presented here would not necessarily score significantly better on an objective test of empathy skills (e.g., Davis 1983) at the end of the modules, but we believe the contrasting ideas in this non-linear trajectory represent, at the very least, a deepening exploration of the role of empathy in engineering and a developing understanding of the complexity of working in socio-technical systems.

The student in the second set of reflections (presented below) seemed to embrace the opportunity to explore empathy in engineering. However, even her

trajectory was not one of linear growth. The reflections presented here are among the most enthusiastic of the group we studied. Like the fifth theme discussed above (*Empathy as a way of being*), the following quotes are also from one of the four female students in the class (although a different student than for above).

1. *'Encountering others is something everyone must do . . . . It is also important for an individual's career. One must utilise this life skill in a way that is effective in building relationships with others. To understand someone and their needs, one has to empathise with what they have to say. This will help an engineer solve problems in a way that is helpful and not harmful to the ones affected.'*

2. *'These exercises hit me really hard because I really want to become better in communicating with others. I want to be respectful and be respected by others in order to have good relationships with the people around me. This is important for my future engineering career because I will have to work not only for other people but also alongside others. Being able to communicate effectively with them is vital. This really helps in preventing conflicts and can be rewarding in the relationships that are formed by it. Since this module, I really have been more aware in how I listen and talk to other people and I hope to continue to make better practice of it.'*

3. *'This has been my favourite module by far and I feel like I gained a lot of out of it not only for engineering but also in daily life . . . It forced me to think through how I converse with others and made me self-aware how I can be a better reflexive communicator . . . This module is something I hope to implement in everyday life and I hope that I can do a great job of doing this in my future career as an engineer. I am currently using this "reflective responding tool" in a sticky situation with family and I am finding that it is really working!'*

4. *'During today's module, I struggled to get my head around . . . how to apply mode switching. This was not easy and it was unnatural . . . Yet mode switching is a good skill to have as an engineer because you need to be able to emphasise with your stakeholders and solve problems at the same time. I am sure I will be trying to perfect this way of communication for the rest of my life.'*

At first glance, this student seems to say all the 'right' things from the very first reflection. The first reflection, however, is written entirely in third person, while in the later reflections the student addresses her responses in the first person. This shift could suggest that the student progressed to more personally engage with her professional identity as an empathic engineer throughout the semester. The student interprets the second module as being heavily focused on communication skills as a tool she can use to succeed in her career while, in the third module, she takes a step towards embracing empathy as a way of being by utilising empathic communication in both personal and professional settings.

This seemingly clean trajectory hits a small snag at the final module, when the student expresses her frustration with attempting to apply mode switching – alternating between analytical and empathic communication – which does not come naturally to her. The excitement expressed in the earlier modules that had provided a space for her to incorporate her natural empathic tendencies in an engineering space is somewhat dampened by the difficulty of cultivating the skill of mode switching. However, the student expresses her determination to continue to foster this skill. With this affirmation, she demonstrates a strong belief that empathy is not a pre-existing ability but can be developed through practice.

This final affirmation that she will work 'to perfect this way of communication for the rest of my life' is powerful. A key message of the modules is that empathy is, in fact, a skill that can be developed and not a stagnant, innate ability (Vallero and Vesilind 2006). While this perspective is promising for students like this one who can build on their natural skills, this growth mindset (Dweck 2016) is critical for students who do not necessarily bring strong empathic abilities into the engineering classroom.

6. Discussion, implications and recommendations

This study has important implications for teaching empathy to engineering students. In the following paragraphs, we offer three observations that may be helpful for instructors who want to use similar approaches in their engineering classes.

First, our findings demonstrate that students come to the classroom with pre-existing mental models about what engineering is and how engineers (should) interact with others. In line with constructivist theories of learning (Mayer 1983; Merrill 1991), these prior mental models significantly impact how students engage with the exercises and experiences in the empathy modules. More specifically, some preconceptions about engineering, for example, around notions of expertise that lend authority to the knowledge held by engineers (Robbins 2007), may lead to tensions with students' efforts to develop deeper, embodied understandings of empathy as an orientation that frames stakeholders as potential partners in their professional endeavours (see 'epistemological openness' in Figure 1). Similar tensions arose around the inherent emotional facets of communication revealed by the modules. Some students struggled to reconcile this dimension of interpersonal communication with their assumptions about the objective, dispassionate stance of the professional engineer (Cech 2014; Leyva, Massa, and Battey 2016). As shown in Figure 1,

however, affective sharing, i.e., the ability to 'feel with' others, is a core skill associated with empathic communication. As instructors, the success of our efforts to foster empathy in our students depends on our ability to understand these mental models so that students can integrate new knowledge, skills, and processes into, ideally, more sophisticated mental models of their own professional selves. At one level, understanding students' prior mental models is critically important in planning empathy exercises. The learning experiences we offer students should both gradually expose students to empathic skills and be situated in pedagogical contexts that are intentionally connected to the development of their engineering identities. The findings show that a focus on skills development without the context of professional application can lead students to discard the experiences as irrelevant or engage in them as a private individual without connecting them to their professional self-perception. Beyond these implications for instructional design, this constructivist perspective becomes particularly important for facilitating debriefing sessions in the classroom and providing after-class reflection assignments, approaches that both offer opportunities for students to reflect on and grapple with pre-existing assumptions they might have about what it means to be and act as an engineer. The quotes show that students' experiences are often emotional and may present significant tensions throughout. Without a recognition of these tensions between prior and developing understandings of engineering, we cannot hope to successfully facilitate these developmental processes in ways that also model the empathic orientations and skills for students.

The second implication from the analysis suggests that the process of developing new understandings regarding the role of empathy in engineering is rarely linear or without conflict. The data analysis revealed that significant variation across students' experiences and responses across the group, a level of disconnect that we, as instructors, need to accommodate in the whole class debriefs. Considering the responses presented in the reflections after module three, some students reject the learning experience entirely (see Theme 1), while others accept the content at a 'skills' level, e.g., communicating with the public is important, but are still grappling with aspects in the orientation dimension (see Theme 2) and are thus, we argue, beginning to engage in transformational processes concerning their professional identity. Being aware of this range can put us in a position to facilitate a shared experience and discussion that does not invalidate student experiences at either end of the range and perhaps can open opportunities for beneficial peer influences in a socio-cultural learning dynamic. We thus encourage instructors to acknowledge and embrace this conflict and embrace modelling of empathy as a core pedagogical tool. Over the past five years of teaching these modules, we have come to understand that it is not our place to be the 'experts' but, rather, to empathise with the emotional experience that can accompany a student who is in the process of reconsidering their pre-existing mental models.

A third implication of the findings and the discussion above concerns fundamental questions of assessment in the context of facilitating a personally relevant, dynamic, context-dependent, and tension-laden developmental process. More specifically, while students can be assessed on their knowledge of specific affective responding techniques (e.g., attending, reflecting emotion, etc.), the most significant learning may lie in unresolved inner conflicts, which are more challenging to evaluate in a traditional view of learning outcomes. The data analysis suggests three features of student learning that may inform a more nuanced view on assessing these types of developmental processes. First, we cannot assume a gradual progression of students towards a common understanding. Students' experiences showed tensions and signs of cognitive disconnect, which led to different students ultimately arriving at quite different, individual understandings of the role(s) of empathy in engineering. Second, the data suggested that these developing understandings of empathy were context-dependent. For example, it is quite possible that students who resisted engaging with emotional aspects of people's experiences *as engineers* (see Theme 1) may be quite capable and willing to discuss emotional aspects of other people's experiences in non-engineering settings. For a detailed analysis on how disciplinary and cultural features of the engineering context intersect with students' development of empathy, we refer readers to (Walther et al. 2020). This context-dependent nature of empathic abilities and development is one reason why we generally refrain from using instruments that claim to measure empathy, such as Davis' (1983) Interpersonal Reactivity Index (IRI). Finally, the findings from this study indicate that the developmental processes we are interested in as engineering educators extend beyond a single course and, likely, beyond the students' entire university experience (see, for example, Theme 4 and the second narrative trajectory). These three features suggest that a productive way to provide evidence of students' learning may not lie in the attainment of outcomes but rather in the depth and genuineness with which they engage in the learning processes. One approach may be to use collective and individual reflection techniques to make this quality of their learning visible, an endeavour that provides both starting points for assessing

student development and, at the same time, an opportunity to actively further their professional growth.

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Notes on contributors

Nicola Sochacka (PhD) is a research scientist and the Associate Director for Research Initiation in the Engineering Education Transformations Institute (EETI) at the University of Georgia. She completed her PhD in Engineering Epistemologies and Bachelor of Environmental Engineering at the University of Queensland. Her research interests include propagating her and her colleagues' work on fostering empathy in engineering to other instructional settings; increasing the capacity of technical faculty to conduct educational research; and using a novel approach called SenseMaker® to investigate and improve engineering student experiences.

Kathryn Youngblood is a Research Engineer at the University of Georgia's New Materials Institute and graduated with a Bachelor of Science in Environmental Engineering from the University of Georgia. As a student researcher, she studied shame and empathy development in engineering students using a variety of qualitative methodologies. Her current work focuses on finding upstream, collaborative solutions to plastic pollution through integrating systems thinking and qualitative research with her background in environmental engineering.

Joachim Walther (PhD) is the Founding Director of the Engineering Education Transformations Institute (EETI) and a Professor of Engineering Education Research at the University of Georgia. His interdisciplinary research programme spans research quality across interpretive methodologies, the role of empathy in engineering formation, and student development in interdisciplinary and interprofessional spaces. Dr. Walther is the recipient of the Presidential Early Career Award for Scientists and Engineers (PECASE). He serves as the Associate Editor for Studies in Engineering Education (SEE).

Shari Miller (PhD) is the Associate Dean and an Associate Professor in the School of Social Work at the University of Georgia. Her research focuses on educational innovation with implications for reflective practice in a sustainable global society. Miller's work has emphasized innovation in social work education, professional socialization, interprofessional models of education and research, theory development, self-care, and environmental social work. She is the recipient of multiple University and national teaching awards, including the Richard B. Russel Award for Excellence in Undergraduate Teaching and the Council on Social Work Education and SAGE Publisher's Award for Innovation in Social Work Education.

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