New Orleans JAZZED about Engineering Education

Paper ID #16286

In Their Shoes: Student Perspectives on the Connection between Empathy and Engineering

Mr. Nicholas D. Fila, Purdue University

Nicholas D. Fila is a Ph.D. candidate in the School of Engineering Education at Purdue University. He earned a B.S. in Electrical Engineering and a M.S. in Electrical and Computer Engineering from the University of Illinois at Urbana-Champaign. His current research interests include innovation, empathy, and engineering design.

Dr. Justin L Hess, Indiana University - Purdue University, Indianapolis

Justin L. Hess received his PhD from Purdue University's School of Engineering Education along with his Master's of Science and Bachelor of Science from Purdue's School of Civil Engineering. Justin is currently a Postdoctoral Researcher in the STEM Education Research Institute at IUPUI. Justin's research interests include developing pedagogical strategies to improve STEM students' ethical reasoning skills; exploring the role of empathy within design, innovation and sustainability; synthesizing the influence of societal and individual worldviews on decision-making; assessing STEM students' learning in the spaces of design, ethics, and sustainability; and exploring the impact of pre-engineering curriculum on students' abilities and career trajectories.

In Their Shoes: Student Perspectives on the Connection between Empathy and Engineering

Abstract

An emerging body of literature highlights the importance of empathy within engineering work and explores how engineering students develop empathic tendencies and utilize empathy during design. Still, more work needs to be done to better understand how engineering students conceptualize empathy and view its role in engineering practice. In this study, we explored the ways that engineering students described empathy and its application in their engineering work. Eight engineering students, from seven different majors, ranging from juniors to doctoral students, participated semi-structured interviews focused on the empathy in engineering. Using thematic analysis we uncovered three themes revealing engineering students' experiences with empathy (understanding others' feelings, important in everyday life, generally outside the scope of engineering) and four themes revealing potential uses for empathy in engineering work (team settings, problem contextualization, human-centered design, individual inspiration). These findings highlight existing gaps between students' perceptions of empathy as compared to scholarly literature on the role of empathy in engineering and perceptions from engineering faculty and practicing engineers. For example, the themes demonstrate that students are often generally aware of certain potential uses of empathy, but have not necessarily experienced those uses in their own work. In the paper, we discuss how alignments or discrepancies between student and expert perceptions both extend our notions of the role of empathy in engineering and identify areas that can be better supported through engineering instruction.

Introduction

Empathy plays a critical role in engineering. Empathy can support effective communication and collaboration across disciplines and cultures, promote more useful and responsive solutions for users, and motivate engineers to incorporate humanitarian and ethical considerations into their solutions[1,2]. Despite, these critical functions, studies suggest engineering students are less empathic than non-engineers and may struggle to incorporate empathy into their engineering work. For example, Rasoal and colleagues[3] found that engineering students scored lower on critical elements of empathy (perspective-taking and empathic concern) than students in other majors (psychology and social work). Similarly, Walther and colleagues[4] posited that one challenge for fostering empathy among engineering students relates to student conceptions of empathy as something other than engineering (e.g., social work). To better understand these issues, we need to explore how engineering students utilize empathy in their work and the factors that affect that utilization.

While an emerging body of literature focuses on the development of engineering students' empathic tendencies and how engineering students utilize empathy during design[5-7], other scholars recognize utilizing empathy requires not only empathic competence, but also a willingness to employ empathy[8]. With this in mind, more work needs to be done to better understand how engineering students conceptualize empathy and view its role in engineering practice. Such understanding can further enhance efforts to promote the development of more

empathic engineers. To fill this gap in the literature, we investigated the ways that engineering students described empathy and its application in their engineering work at a large public Midwestern University. As such, this study was guided by the following research questions:

1. How do engineering students describe their experiences with empathy?
2. From the perspective of engineering students, what is the role of empathy in engineering?

Literature Review

Empathy is a complex phenomenon with cognitive, affective, and behavioral components that interact in nuanced ways. While there is no unified framework regarding how empathy manifests, common elements exist. For example, empathy can be initiated through an instantaneous somatic or emotional response to another's situation[9-11] which can manifest either through emotional congruence or contagion.[12] In turn, this transformed emotional state can alert one to the emotional salience of the situation and/or another's internal emotional state, and allow one to accurately understand another's situation. However, one's empathic accuracy is influenced by several factors, including one's ability to regulate one's own emotions and one's general awareness of the self as similar to, but also distinct from, the other.[9] In sum, these processes can, but do not necessarily, result in an empathic understanding of the internal state (i.e., feelings, thoughts, perspectives) of another. Although the empathic understanding is not always accurate[13,14], it may result in affective feelings of empathic concern[15] or emotional distress[16], which if regulated effectively[10] can inspire helping behavior[11,17]. Some authors even depict this helping response as part of empathy[15]. In the context of engineering, this helping behavior is often portrayed in the form of caring for stakeholders[2,18] or developing user-appropriate design solutions[5,8], but may take other forms, such as in effectively communicating[4], innovating[19], or making ethical decisions[20].

A limited number of studies have explored the empathy among engineering students. Some of these studies have explored the empathic characteristics engineering students display[3,19]. Others have focused how and under what conditions students use empathy during the design process[5,21,22] and the effects empathy has on student design solutions[6,23]. These studies suggest that empathy is more prominent[22,24] and more useful when student designers interact with and are immersed in the user context. But they also present unfavorable comparisons to non-engineers (e.g., students in healthcare fields) on key empathic dispositions[3] and limited relationships between affective empathic dispositions and innovative behavioral tendencies[19].

In the context of engineering, successfully utilizing empathy requires both a willingness to behave empathically and skill at developing and translating empathy into meaningful engineering action[8]. Willingness or opportunity to utilize empathy may be inhibited in many engineering settings, even those nominally dedicated toward empathic design[25]. Thus, more work needs to be done to understand empathy and its perceived role in the engineering context from the student perspective. Such investigation could be useful for identifying opportunities and strategies for empathic training, and also suggest how engineering culture, at least from the student perspective, could be modified to support more empathic design processes and engineering work.

Theoretical Framework

This study is rooted in a social constructionist theoretical framework. Social constructionism emphasizes how or in what ways a particular *social group* gives meaning to and jointly constructs a phenomenon[26-28]. In this case, the social group is engineering students at a large public university in the U.S. and the phenomenon is empathy. Meaning arises from that group's interaction with the social world, which comprises human participants, artifacts, and other environmental factors. In engineering education (the primary shared context of this social group), such a world can comprise a course setting, co- and extracurricular projects and activities, interactions with peers (i.e., fellow students), or any other common experiences that link the students to the phenomenon being studied. Thus, we theorize that the discussions of empathy presented in this study directly reflect the phenomenon of empathy as it is developed, interpreted, and experienced in the unique context of engineering education by engineering students.

From a social constructionist perspective, meaning is developed and conveyed through language[27]. Thus, in this study, we pay particular attention to language as a lens to explore the phenomenon of empathy in the social world of engineering students. As such, this study focuses on using qualitative interview data to provide a lens into the students' social world. One implication of this focus was that we did not provide an explicit definition of empathy to the students. Notably, we felt that this lens was important due to the lack of discourse on empathy in engineering[2]. Empathy is an emergent topic that will mature as its role and presence is explored and articulated in new contexts[29].

Methods

Participants

Participants in this study included eight engineering students from a single large public university in the midwestern United States. These students represented various majors, levels of education, and genders. Table 1 presents a summary of the participants, listed by pseudonym.

Table 1. Overview of Engineering Student Participants

Participant	**Major**	**Year in School**	**Gender**
Donovan	Biological Engineering	Junior	Male
Henrik	Computer Engineering	Masters student	Male
Julie	Agricultural Engineering	Masters student	Female
Karl	Chemical Engineering	Junior	Male
Luiz	Biological Engineering	Junior	Male
Mike	Electrical Engineering	Doctoral student	Male
Roxanne	Civil Engineering	Senior	Female
Terence	Aeronautical Engineering	Doctoral student	Male

To recruit participants, we disseminated a survey that included a validated psychometric instrument to measure students' empathic tendencies, the Interpersonal Reactivity Index[30]. To recruit participants, we shared the survey link and a recruitment e-mail with administrators of

departmental list-servs at the university. Upon completion of the survey, we invited students to participate in a follow-up interview for which they would be compensated ten dollars. From this pool of volunteers, we interviewed eight engineering students from seven different majors, ranging from juniors to doctoral students. The diversity (in terms of academic major, year in school, and gender) presents a wide social group through which to explore the role of empathy, but the participant pool is noticeably limited in number and restricted as the participants attend the same university. Thus, the results of this study are preliminary.

Data Collection

We conducted interviews over a three-week period. Both authors were present at six of the interviews, but due to scheduling constraints, only the first author interviewed Donovan and Mike. The semi-structured interviews ranged from 40–90 minutes and elicited students' perspectives on empathy both inside and outside the context of engineering work. We utilized a common set of open-ended questions to probe students' perspectives at a general level, along with follow-up questions to add clarity and detail to students' responses and to further explore salient or novel aspects of the participants' previous responses. Portions of these interviews were not related to empathy (approximately half of the interview time), and we did not consider these portions during this analysis. Each of the interviews were audio recorded and transcribed by the authors.

Data Analysis

We utilized thematic analysis[31] to explore the ways engineering students described their experience with empathy and the role they perceived empathy to play in engineering work. We utilized a six-step process as outlined by Braun and Clarke[31]. These steps included:

1. Reading and re-reading the data
2. Generating initial codes
3. Collating codes and identifying themes
4. Reviewing themes in light of coded extracts and the whole data set
5. Defining and naming the themes
6. Crafting final theme descriptions and maps

This process was iterative and we frequently shifted between steps. Throughout the process, we ensured that all findings originated from the data and fit within the fabric of individual excerpts, the whole data set, and the literature on engineering students and empathy. Thus, we consistently referred back to the data, each other, and relevant literature when refining themes and their descriptions. The process was completed when we believed the themes were stable, consistent, and accurately represented the participant responses as a whole.

Results

Thematic analysis revealed three themes related to engineering students' experiences with empathy (RQ1) and four themes related to engineering students' perceptions of the role of

empathy in engineering (RQ2). Table 2 provides a description of these themes, which we further explore in the subsequent sections.

Table 2. Overview of Themes

Category	**Theme**
Experiential: *Empathy described as…*	Understanding Others' Feelings
	Important in One's Everyday Life
	Generally Outside the Scope of Engineering
Engineering Utilization: *Empathy is applicable in…*	Team Settings
	Problem Contextualization
	Human-Centered Design
	Individual Inspiration

Experiential Themes

Each of the three experiential themes encapsulates how students described empathy and its relevance within their daily life and their engineering academic and professional experiences. In the following sub-sections, we describe each theme and embed quotations directly from the interview transcripts.

Theme 1: Empathy as Understanding Others' Feelings

Students unanimously described empathy as understanding others' feelings. For example, Julie described empathy as "knowing how other people are feeling when they're going through a situation." This is a relatively simple definition that focuses on the cognitive component of empathy (understanding another), but one that also focuses on the role of cognition for understanding another's affective state. Julie continued her definition with, "Being able to guess how someone feels."

Some students elaborated on this basic definition by stating the cause or outcome of such empathy. Terence, for example cited emotional contagion (i.e., matching another's emotional state) as a physiological cause of empathy. On the other hand, Donovan, Henrik, and Luiz cited elements of empathic concern or care as resulting from understanding another's feelings. In this way, some students incorporated both cognitive and affective components to empathy. Despite alternative phrasings and additional elements, all students' definitions focused on these two elements (understanding others and directing that understanding at feelings). Further, some students added a behavioral element of acting compassionately based on one's understanding and care for another. For example, Donovan stated:

> *Understanding someone else's feelings, I guess. And then being able to put yourself in that person's shoes and then kind of understand where they come from. And then, I guess, be able to console someone in that kind of position, if they need consolation.*

Theme 2: Empathy as Important in One's Everyday Life

Alongside students' definitions of empathy, all but two of the students (Mike and Terence) described themselves as moderately to highly empathetic individuals. The self-described empathizers indicated that, in everyday life, they regularly considered others' feelings and, as a result, demonstrated helping behavior. For example, Donovan indicated, "I think I have a lot of empathy," and backed up this assertion with helping examples, including, "If someone falls down I'll try to help 'em up," and "if someone drops a coffee I'll buy them another coffee." Although Donovan did not articulate whether his empathic actions were a result of empathic concern (e.g., feeling bad for his friend), self-oriented understanding (e.g., imagining about how you feel if you dropped a coffee), or some combination of both, it seemed important for Donovan that his empathy translated into some action.

Both Donovan and Luiz felt that they became empathetic as a result of how they were raised. Conversely, for Julie, empathy was something she had fostered through knowing "a lot of people" and sharing new experiences. She described empathy as a product of "how much you care to learn about the world." Henrik and Karl honed their empathy through significant social relationships, where peers (e.g., their friends, significant others, classmates) indicated they needed to behave more empathically. As the students reported responding to such remarks with genuine attempts at empathy, they generally experienced positive effects of such efforts, which reinforced the importance of empathy within their everyday lives. As Henrik described:

> *Oh, man! I had a girlfriend that, well she would complain that I wouldn't sympathize or empathize. One or the other. But I was in a very logical, cold, factual place. And I didn't really see the point of emotions and feelings in things. So she introduces me to those words… I find it, the more I allow myself to be empathetic, the more I do it… I guess I see good things happen when I do it. Reinforcement of that behavior doing good things for me.*

Theme 3: Empathy as Generally Outside the Scope of Engineering

Despite the importance of empathy in their personal lives, students saw a limited role for empathy in their engineering work. At a broad level, students attributed this to the strongly technical, logical, and analytical nature of engineering work. They felt that oftentimes, the mindset necessary for this type of "objective" work conflicted with the mindset necessary to empathize with another human being. Karl described how internalizing the problem-solving/objective mindset influenced his personal relationship with his wife:

> *If my wife has a problem with something she knows not to even bring it up right when I get home because I've just been doing engineering all day. Being very objective. Problem-solving. You know, solve, solve, solve. And if I get home and she brings up something that's bothering her, the first thing I think of is like, "Okay, let's figure out how to fix it." And I don't know if you've ever experienced this, but a lot of times women, and men, when they're having, you know, emotional problems, they just want to talk about it. They don't really want a solution. But I just spent the past 8 to 10 hours solving things, so the first thing I want to do is solve it. And so, I had a friend who had this problem and he*

> *just said, "Yeah, we just decided that the first 30 minutes I just need to like kind of unwind and get back into, you know, I'm not solving the world's problems at home. I'm trying to, you know, be a good husband and father." And so, I guess in that way engineering actually does affect me, maybe in a negative way. Because I'm thinking, what makes me feel good is solving a problem but that's not necessarily what makes you feel good right now.*

Outside of conflicting mindsets, many students saw a lack of utility or opportunity for empathy in their work. From their perspectives, their work had little to do with other people (e.g., end-users) and therefore empathy did not come into play. From Julie's work at a water treatment plant to Mike's time in the fabrication laboratory to Donovan's experiments with fish oil and water emulsions, students did not see how empathy for others would be useful. As Roxanne put it, "There's not a whole lot of empathy you can give a building." To Julie, this disparity was not a matter of not being empathic, but doing what was appropriate for the task at hand.

> *So, we [most engineers] don't necessarily have a concept of empathy in society as much. But we might have just as much empathy in our daily lives as the average person, and I think that if someone is designing, I don't know, my boyfriend designs concrete anchors for facades on buildings and I don't think he thinks about that. You know, he thinks about whether or not it's gonna collapse. He doesn't think about the larger picture. I don't know if it would be appropriate to do that?*

These broader perceptions may be tied to students' lack of experiences with empathy in their engineering courses. For example, when asked how she experienced empathy in engineering curricula, Roxanne stated, "I don't think I have at all." When asked if empathy was portrayed in his coursework, Karl responded, "Not particularly" but "maybe in the senior design course where we're actually making something." Karl indicated that the delivery of much engineering training implicitly de-emphasizes empathy. As he stated, "I think as an engineer you're often trained to think of things objectively and sometimes that kind of negates people's feelings. Because you feel like you know what's best for them so they should just deal with what you're giving them." As the end of his interview, Karl stated:

> *I know that all of my experience with use case studies, and all, that's all been in industry. I didn't learn any of that in college. Except for, like I said, that senior design class. Which you take right before you leave… I think the technical stuff is important and I'm not sure if you would want to water it down or distract, but maybe it's not good to have those classes, like the one class that I took that actually asked me to ask somebody else what they would want. I didn't take it until my last semester in college and like maybe it would have been nice to take a few of those earlier.*

Still, upon reflection and through engagement with the conversation, many of these students saw opportunities for empathy in engineering work. For example, several students referenced biomedical engineering, or anything that required interaction with an end-user. Interestingly, Julie, who did not see much of a role for empathy in her own work or the work of those near to her, recognized that she became frustrated when interacting with engineering artifacts as the end-user when it was obvious that the engineer did not consider her perspectives and feelings.

Engineering Utilization Themes

The next four themes pertain to students' perceptions of potential uses for empathy in engineering work. These perceptions may have been based on students' engineering experiences, or their general perceptions of the possibilities of engineering work.

Theme 4: Empathy in Team Settings

Students perceived empathy to be particularly important in a team setting. Here, students relied on the cognitive elements of empathy to understand their teammates' feelings and viewpoints (i.e., through perspective taking). They felt that empathy, in these collaborative contexts, was necessary to maintain social harmony, allow compassion for struggling teammates, place teammates in positions to succeed by delegating work they can handle, and, as Mike indicated, ensuring good communication and trust so that diverse views within the team could be used.

> *Perspective taking, I've personally had a lot of experience with this with teamwork. I worked in a group that had some very strong personalities… One of the members of the group had a lot of really great ideas. We wanted to have him around for that, but if he didn't understand something he assumed you were saying something that was completely stupid and was not following physics and he would get caught up on this other detail and not let the idea get fully explained. And so, without that perspective-taking, he was having issues with not trusting the other person to be proposing an idea that they thought was good, and trying to see where the merit was, and not getting hung up on these other details. And perspective-taking is also something I used in figuring out where the source of this problem was, because it was a very common problem that was giving us a lot of grief. So, looking at it from his perspective, and finally figuring out, okay, this is how he thinks, and then developing a solution to that communication issue.*

Karl, talking about personal distress, highlighted the notion that when one is a source of distress (e.g., aggressive), then they are not a great collaborator. Thus, a lack of empathy among teammates can also lead a students to diminish their contributions to the team. As he stated:

> *To ask somebody a question is admitting that you don't know the answer, right? Well, unless it's like a divisive question. And I'm not going to open myself up to somebody if I've seen them tear into somebody else for asking a question or maybe missing a deadline or something. I'm gonna feel like, well that person's not really gonna, they're looking out for themselves, not helpful for others.*

Theme 5: Empathy in Problem Contextualization

Despite the technical nature of most of their work, several of the students acknowledged that engineering solutions exist in the human world. These solutions are used by and affect others, and thus, they felt that user perspectives needed to be taken into consideration during the design and development of such solutions. Here, empathy provides an opportunity to contextualize a technical design problem in the human realm, which can allow the engineer to see why a

technically sound solution might fail and can point the engineer to a more useful path. For example, Roxanne described her experience of thinking about end-users during a class project:

> *I think the better understanding you have of someone's problems or the problem in general or how someone uses something, the better you're gonna be able to get at the actual root of the problem… Going back to the class I was in earlier, there was some amount of empathy in that, because we're looking at solving environmental problems for a large city. So you're looking at changing behaviors and trying to figure out how you can encourage people to change their behavior when they, obviously, don't want to change their behavior and they don't want to do something or have less of something or pay more for something… So using empathy in that matter and saying, "But what could we do to encourage them?" So having to put yourself in their situation and their perspective and thinking of innovative results around that.*

Similarly, students like Mike and Terence considered empathy to be most useful for attempting to ensure that design solutions were ethical and responsible given the human context. This process included putting a human face to quantitative safety analysis, but also considering potential and unforeseen negative effects of implementing a solution on the user and surrounding community. As Terence noted:

> *As an engineer you're building things, right? So you're building things, and you obviously should make sure that the human beings using it should not face problems with it. For example, I have my phone in my pocket all the time. Right, if the battery catches fire, if it overheats and catches fire, then—I mean, I could be sleeping with my phone in my pocket, right?*

Theme 6: Empathy in Human-Centered Design

The previous theme described empathy for end-users as a means to promote the ethicality and usefulness of technical engineering solutions. In addition, some students perceived empathy to be useful when designing for end-users and in driving their technical work. Thus, they framed empathy less as a checkpoint, but more as a building block. Here, a deep understanding of the user and their context allows the engineer to identify key issues and problems, identify user-appropriate solutions, and develop solutions to help people. Specifically, many students noted the applications to consumer products or medical-assistive devices. For example, Henrik stated:

> *If we're making solutions for people, then we have to empathize with them—where they will be and how they'll be feeling and all that good stuff—to make a good, usable solution that will make a difference, that they'll actually use. Effective. Because anyone can solve a problem, but if you like using it and someone gives you something that you think feels nicer for whatever reason, then they made a better product. And maybe they empathize more with your context.*

Theme 7: Empathy in Individual Inspiration

Each of the previous three themes referred to the cognitive components of empathy (i.e., understanding the perspectives and feelings of others) as supporting engineering work. Students also observed the potential effect of the affective components of empathy for driving engineering work. More specifically, students saw empathic concern for others as a potentially motivating force in their work. Tied to the ethical elements of contextualizing the technical problem, Roxanne saw the importance of doing a good job when her solutions directly affected others. Thus, empathic concern would cause her to work harder when the stakes were higher. For others like Donovan and Karl, concern for stakeholders could draw them to specific projects or lines of engineering that would allow them to help others. Donovan saw empathically motivated projects as a future prospect, but Karl chose to work on medical implantable devices for that very reason, stating:

> *In most medical device companies, I mean there's more money to be had elsewhere. And it's easier. I mean, if I wanted to just make money I'd go make consumer electronics or I'd go be a stock broker or something. I'm not saying they don't have empathy, but a huge mission for people who go into medical implantable devices is that they want to help people. And, so that's kind of an underlying mission statement… When you're developing medical implantable devices you have to deal with all sorts of regulatory things that you don't have to deal with in other products. There's a lot of constraints that you have to deal with that other people don't have to deal with. It makes things, engineering-wise maybe a little less exciting… but at the same it makes it more exciting to me because you're dealing with greatly enhancing people's lives and saving lives.*

This inspiration could be to an external design project, but it could also be for building solidarity among team members. For example, Luiz (whose propensity for empathic concern for others was evident throughout his interview) described a situation where he felt bad for a teammate who (unbeknownst to the rest of the team) was picking up *her* friend's slack. Luiz decided to help this teammate by taking on some of the extra she had work received from her free-riding friend.

Discussion

These findings highlight existing gaps between students' perceptions of empathy as compared to scholarly literature on the role of empathy in engineering and perceptions from engineering faculty and practicing engineers. While students generally saw potential for empathy in engineering work, they did not often utilize empathy in their own work. This finding was further surprising as many of the students claimed moderate to strong empathic tendencies and provided salient examples of behaving empathically in their daily lives. Broadly, these findings represent potential inability or unwillingness to incorporate empathy into engineering work. We discuss some potential causes below.

Lack of Empathy Training within Engineering Curriculum

One potential explanation for the disconnect between empathy and engineering, as evidenced by participants responses throughout this study, could be the lack of empathy training they

encountered within their coursework. Students struggled to identify instances in which the term "empathy" was explicitly used by instructors. Among the few exceptions (senior design and specialized elective courses), empathy training did not reach students until the tail-end of their formal education, or by a narrow sample of students who were interested in a particular niche topic area. Effects of this disparity can be seen in the lack of nuanced understanding of empathy (e.g., the *Empathy as understanding others' feelings* theme) and their limited number of self-described empathic engineering experiences. For example, several students attempted to differentiate empathy with the related construct of sympathy (by their own prompting) but found their own responses to be approximations (as evident through their explicitly stated uncertainties). More comprehensive empathy training (e.g., tools through which to apply one's natural empathy) could prove useful, but that would assume students simply lack the awareness and ability to translate empathy from their daily lives into engineering contexts, which may not necessarily be the case. Rather, many engineering students might be attracted to engineering as a result of the broader stereotypes of the profession as un-empathic[2].

Stereotypes Portray Empathy as Misaligned with Engineering Work

The *Empathy as outside engineering* theme demonstrated that the challenge of infusing empathy within engineering curricula may directly result more from students' willingness to apply empathy to engineering work. Similar to the concerns voiced by Walther and colleagues[4], when trying to inculcate empathy directly, students may perceive empathy as something other than engineering. Several students seemed to equate anything related to empathy as less objective and therefore as a part of non-engineering work. For example, Roxanne suggested that empathy was useful in "project management" but "not necessarily towards our actual work."

However, these same students saw potential uses of empathy within engineering but were either unable or unwilling to embrace them. Luiz, for example, struggled to articulate much of the utility of empathy within engineering, but had no difficulty associating empathy with innovation. Interestingly, to ground this suggestion, Luiz described a water gardening project from his first-year engineering course to articulate this relationship. Thus, the disconnect may be in students' perceptions of engineering work, and strengthening the connection between empathy and engineering according to engineering students may require a culture shift.

Other responses presented the disconnection at a deeper level. Karl, who had positive experiences with empathy when working on human-centered design projects, suggested that the difficulty connecting empathy to engineering is the technical mindset required for much engineering work. As Henrik noted, even in situations where empathy may be salient (e.g., designing with particular users in mind), it may be easy to lose sight of the users in the technical details of the design. One way to view these responses is to suggest that an empathic mindset may be incommensurable with the technical mindset students view/experience as necessary to engineering. Alternatively, it may be that students need support for maintaining empathy throughout projects in which the technical focus remains strong. Henrik, for example, when reflecting upon his senior design project noted the potential benefit of thinking and behaving empathically towards the users.

Certain Engineering Experiences Promote Positive Perceptions of Empathy in Engineering

Experiences with real-world partners and users, in coursework or internships, allowed some students to experience empathy firsthand in their engineering work[6,20]. Such experiences seemed to play a similar role here, allowing students to move beyond "technical" stereotypes. For example, reflecting on his experiences as an engineer, Karl fluently articulated numerous instances where empathy was useful, from developing devices for epilepsy patients to senior design coursework where he interacted with EMTs. Several undergraduate students lacked such experiences, and therefore tended to focus on their routine class work. The lack of interactions with real-world partners likely influenced many of these students' to rely on negative stereotypes. Increasing opportunities for such immersive projects could provide an organic means of demonstrating the utility of empathy within engineering. Yet, providing students with support or reflections on the people part of engineering, particularly when projects become "too technical," may be required to foster more positive student perceptions on the role of empathy in engineering.

Conclusion

This study presented a qualitative analysis of how engineering students describe their experiences with empathy and the role empathy plays in engineering. Specifically, students described four potential uses for empathy within engineering, including supporting effective teamwork, problem contextualization, human-centered design, and individual inspiration. Despite these potential uses, many of the students had not experienced or consciously utilized empathy firsthand in any engineering context. Students described empathy, especially the affective component, as largely external to engineering. While the scope of this study may be limited by the number of participants (who all attended the same university), these results suggest some challenges (both experienced and perceived) that students may face utilizing empathy in their engineering work. These challenges included incommensurability between the technical and empathic mindset, overcoming student perceptions of empathy as external to technical work, and the lack of training for developing empathy in an engineering setting.

Future Directions

Challenges identified within this study provide a basis for future research and instruction related to empathy in engineering. For example, future researchers might extend and add nuance to the findings generated herein by interviewing a larger sample of engineering students or by comparing the empathic design practices of novice versus expert engineering designers in varying contexts. Separately, future researchers might corroborate these findings by exploring their own students' perceptions of the role of empathy within engineering.

Acknowledgements

This material is based upon work supported by the National Science Foundation Engineering Education Program under Grant No. 1150874. Any opinions, findings and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

References

1. Bucciarelli, L. L. (1994). *Designing engineers*. Cambridge, MA: MIT Press.
2. Strobel, J., Hess, J. L., Pan, R. C., & Wachter Morris, C. A. (2013). Empathy and care within engineering: Qualitative perspectives from engineering faculty and practicing engineers. *Engineering Studies, 5*(3), 137-159.
3. Rasoal, C., Danielsson, H., & Jungert, T. (2012). Empathy among students in engineering programmes. *European Journal of Engineering Education, 37*(5), 427-435.
4. Walther, J., Miller, S. I., & Kellam, N. N. (2012). *Exploring the role of empathy in engineering coummunication through a trans-disciplinary dialogue*. Paper presented at the American Society for Engineering Education Annual Conference, San Antonio, TX.
5. Fila, N. D., & Hess, J. L. (2015). Exploring the role of empathy in a service-learning design project. In R. S. Adams & J. Siddiqui (Eds.), *Analyzing Design Review Conversations* (pp. 135-154). West Lafayette, IN: Purdue University Press.
6. van Rijn, H., Sleeswijk Visser, F., Stappers, P. J., & Özakar, A. D. (2011). Achieving empathy with users: The effects of different sources of information. *CoDesign, 7*(2), 65-77.
7. Kwok-leung Ho, D., Ma, J., & Lee, Y. (2011). Empathy @ design research: a phenomenological study on young people experiencing participatory design for social inclusion. *CoDesign, 7*(2), 95-106.
8. Kouprie, M., & Sleeswijk Visser, F. (2009). A framework for empathy in design: Stepping into and out of the user's life. *Journal of Engineering Design, 20*(5), 437-448.
9. Decety, J., & Moriguchi, Y. (2007). The empathic brain and its dysfunction in psychiatric populations: Implications for intervention across different clinical conditions. *BioPsychoSocial Medicine, 1*(1), 22.
10. Decety, J., & Jackson, P. L. (2004). The functional architecture of human empathy. *Behavioral and Cognitive Neuroscience Reviews, 3*(2), 71-100.
11. Hoffman, M. L. (2000). *Empathy and moral development: Implications for caring and justice*. Cambridge, UK: Cambridge University Press.
12. Hatfield, E., Cacioppo, J. T., & Rapson, R. L. (1994). *Emotional contagion: Studies in emotion & social interaction*: Cambridge University Press.
13. Ickes, W. J. (2009). Empathic accuracy: Its links to clinical, cognitive, developmental, social, and physiological psychology. In J. Decety & W. Ickes (Eds.), *The social neuroscience of empathy* (pp. 57-70). Cambridge, MA: MIT Press.
14. Ickes, W. J. (1997). *Empathic accuracy*: Guilford Press.
15. Davis, M. H. (1996). *Empathy: A social psychological approach*. Boulder, CO: Westview Press.
16. Eisenberg, N., Fabes, R. A., Schaller, M., & Miller, P. A. (1989). Sympathy and personal distress: Development, gender differences, and interrelations of indexes. *New Directions for Child and Adolescent Development*(44), 107-126.
17. Oxley, J. C. (2011). *The moral dimensions of empathy: Limits and applications in ethical theory and practice*. New York, NY: Palgrave Macmillan.
18. Strobel, J., Morris, C. W., Klingler, L., Pan, R., Dyehouse, M., & Weber, N. (2011). *Engineering as a caring and empathetic discipline: Conceptualizations and comparisons.* Paper presented at the Research in Engineering Education Symposium, Madrid, Spain.
19. Hess, J. L., Fila, N. D., Purzer, Ş., & Strobel, J. (2015). *Exploring the relationship between empathy and innovation amongst engineering students*. Paper presented at the American Society of Engineering Education Annual Conference, Seattle, WA.
20. Vallero, D. A. (2008). Macroethics and engineering leadership. *Leadership and Management in Engineering, 8*(4), 287-296.
21. Fila, N. D., & Hess, J. L. (2014). *Exploring the role of empathy in a service-learning design project*. Paper presented at the DTRS 10: Design Thinking Research Symposium 2014, West Lafayette, IN.
22. Zoltowski, C. B., Oakes, W. C., & Cardella, M. E. (2012). Students' ways of experiencing human-centered design. *Journal of Engineering Education, 101*(1), 28-59.
23. Johnson, D. G., Genco, N., Saunders, M. N., Williams, P., Seepersad, C. C., & Hölttä-Otto, K. (2014). An experimental investigation of the effectiveness of empathic experience design for innovative concept generation. *Journal of Mechanical Design, 136*(5).
24. Fila, N. D., Hess, J. L., Dringenberg, E., & Purzer, Ş. (in press). Exploring the role of empathy in a decontextualized engineering design task. *International Journal of Engineering Education, 32*(2).

25. Postma, C. E., Zwartkruis-Pelgrim, E., Daemen, E., & Du, J. (2012). Challenges of doing empathic design: Experiences from industry. *International Journal of Design*, *6*(1), 59-70.
26. Patton, M. Q. (2002). Two decades of developments in qualitative inquiry: A personal, experiential perspective. *Qualitative Social Work*, *1*(3), 261-283.
27. Young, R. A., & Collin, A. (2004). Introduction: Constructivism and social constructionism in the career field. *Journal of Vocational Behavior*, *64*(3), 373-388.
28. Baillie, C., & Douglas, E. P. (2014). Confusions and conventions: Qualitative research in engineering education. *Journal of Engineering Education*, *103*(1), 1-7.
29. Kunyk, D., & Olson, J. K. (2001). Clarification of conceptualizations of empathy. *Journal of Advanced Nursing*, *35*(3), 317-325.
30. Davis, M. H. (1983). Measuring individual differences in empathy: Evidence for a multidimensional approach. *Journal of Personality and Social Psychology*, *44*(1), 113-126.
31. Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77-101.