International Journal of Engineering Education Vol. 40, No. 6, pp. 1323–1338, 2024
Printed in Great Britain
0949-149X/91 $3.00+0.00

A Collaborative Inquiry into Tensions between Empathy and Engineering Design*

COREY SCHIMPF
Department of Engineering Education, University at Buffalo, SUNY, 140 Capen Hall, Buffalo, NY, 14260, USA.
E-mail: schimpf2@buffalo.edu

NICHOLAS D. FILA
Department of Electrical and Computer Engineering, Iowa State University, 343 Durham, Ames, IA, 50011, USA.
E-mail: nfila@iastate.edu

JUSTIN HESS
School of Engineering Education, Purdue University, Armstrong Hall, West Lafayette, IN 47907, USA. E-mail: jhess@purdue.edu

ALLISON GODWIN
Smith School of Chemical and Biomolecular Engineering, Cornell University, 246A Olin Hall, Ithaca, NY 14853, USA.
E-mail: afg64@cornell.edu

ELIZABETH SANDERS
School of Engineering Education, Purdue University, Armstrong Hall, West Lafayette, IN 47907, USA. E-mail: sande117@purdue.edu

KIRSTEN H. DODSON
Department of Mechanical Engineering, Lipscomb University, One University Park Drive, Nashville, TN, 37204, USA.
E-mail: Kirsten.Dodson@lipscomb.edu

MOLLY H. GOLDSTEIN
Department of Industrial and Enterprise Systems Engineering, University of Illinois Urbana-Champaign, 309 Transportation Building, Urbana, IL, 61801, USA. E-mail: mhg3@illinois.edu

ROB SLEEZER
Department of Integrated Engineering, Minnesota State University Mankato, 9700 France Ave South, Ste P0820, Bloomington, MN, 55431, USA. E-mail: robert.sleezer@mnsu.edu

Empathy has received increased attention for its role in engineering design. While research on empathy in engineering and engineering design is still relatively new, there are already several definitions or models of empathic design for engineers. Moreover, there are a variety of ways that scholars have integrated empathy into engineering design curricula. In this study, to better understand how instructors can integrate empathy into engineering design curricula and unveil the benefits, opportunities, and challenges of its integration, eight engineering design instructors formed a collaborative inquiry (CI) group. In CI, members act as researchers and participants to collectively explore their experiences with a topic of interest. The participant-researchers of the CI group for this study formed out of a larger project that seeks to create a model of empathy in engineering design and instrumentation to assess the model's manifestation in students' engineering design experiences. In this larger project, several tensions emerged related to empathy's integration into engineering design education. In response, we formed the CI group to address the question, "What tensions are experienced by engineering design researchers and educators regarding the construct of empathy in our educational practice?" Tensions recognize that problems or challenges may have two or more responses. The CI team met six times to identify tensions regarding empathy in engineering design as experienced in their teaching practice. Through our collaborative inquiry, we generated a model that represents our understanding of these tensions. The model included ten themes, which included four empathy frames (definition, value, manifestation, and pragmatics) and six intersections between these frames. Our results share insights from our discussion on five of the ten themes. We close the paper by reflecting on the model and the process of building the model. We offer that the model can be useful for other design instructors to integrate empathy into their curriculum and practices for thoughtfully responding to these tensions. We hope this work can help extend and facilitate ongoing research on empathy in engineering design.

Keywords: engineering design; empathy; collaborative inquiry; tensions framework

1. Introduction

Empathy has received increased consideration in engineering design over the last few decades. Empathy's emergence is a relatively new area of scholarship in engineering and engineering education, yet scholars have offered various ways of defining empathy [1–4], teaching empathy in engineering [5, 6], and integrating empathy in engineering design [7, 8]. This multiplicity and newness can

* Accepted 10 September 2024.

lead to both uncertainty and variation in how instructors introduce empathy into their classrooms and curricula.

In this work, we embrace and foster dialogue across several perspectives on empathy and engineering design through collaborative inquiry. Collaborative inquiry (CI) is a participatory research approach where participants act as researchers and aspire to build shared understanding on a topic of interest [9]. In alignment with the 2023 Harvey Mudd Design Workshop (MDW) vision, we aspired to discuss and share approaches for building bridges, creating connections, and removing obstacles to bringing empathy into engineering design curricula. We worked towards this vision by focusing on tensions.

Cheville & Haywood [10] defined tensions in terms of "stretch," wherein there exist "elements of balanced but opposing forces, latent hostility, and being stretched between fixed points." As they write further, "Tensions are by definition at least dipoles," which are "dialectical in nature." We draw on Cheville and Heywood's definition of tensions as our conceptual framework for this study as it aligns with extant work on empathy, such as Cuff et al. [3], who defined eight dialectic themes or tensions common across definitions of empathy. Tensions have also been increasingly the subject of research in design [11, 12] and engineering education [13–15]. Moreover, using tensions as a conceptual framework allows us to retain a fuller view of the multifaceted challenges, differences in perspective, and latent conflicts that arise when bringing empathy into engineering design.

This paper is situated in the context of a larger project that aims to leverage co-creation to generate a model of empathy in engineering design [16]. The larger project includes approximately 15 design educators across ten universities in the United States. Five educators from this group led the overarching research effort, while the other ten educators served as collaborators to help develop the aforementioned empathy model. Educators' instructional contexts differed by engineering discipline (e.g., biomedical, systems), course type (e.g., first-year engineering, junior design, senior design), and course topic (e.g., medical device design, humanitarian engineering, community engagement). After some of our early co-creation workshops, the research team and collaborators discovered that they were struggling with divergent definitions of empathy and, in turn, competing perceptions of empathy's role in engineering design. A subgroup of the larger team decided to undertake a CI approach which was aligned with but beyond the original grant scope. Through CI, we aimed to better understand the tensions we felt and experienced regarding engineering design and empathy.

In this study, we addressed the research question, "What tensions are experienced by engineering design researchers and educators regarding the construct of empathy in our educational practice?" These tensions may be internal (i.e., uncertainties or disparate viewpoints held by an individual) or external (i.e., uncertainties or disparate viewpoints across individuals, cultures/contexts, or between an individual and prevailing cultures/contexts). Further, tensions may exist in framing empathy as a construct, how empathy manifests in engineering design, or how instructors incorporate empathy into engineering design curricula and courses. We sought to leverage our collective and unique experiences to uncover the most salient tensions in this space.

In the remainder of the paper, we first present background on tensions for defining empathy in extant research. Next, we discuss our conceptual framework, introduce collaborative inquiry, and discuss our process for meeting and identifying tensions. Third, we present a synthesized model of tensions which emerged from our collaborative inquiry. Fourth, we provide a thick description of five of ten themes within the model. Finally, we discuss the team's reflections on the model and how this effort can inform teaching practices in engineering education.

2. Background and Motivation

2.1 Tensions when Defining Empathy

Colloquially, empathy refers to thinking and feeling as another. However, there are competing viewpoints on what empathy is (and what it is not). Here, we briefly outline the definitional tensions offered by Cuff et al. [3]. These authors recognized eight tensions in defining empathy: (1) whether empathy is cognitive (e.g., focused on thoughts and understanding) or affective (e.g., focused on experiences and emotions) in nature; (2) whether empathy requires sharing identical emotions as another, like-emotions, or neither; (3) processes for activating empathic states, (4) self-versus-other differentiation or alignment, (5) the importance of context, (6) whether behavior is necessary for true empathy, (7) whether empathy is something one can control, and (8) differentiating between empathy and sometimes synonymously used terms (e.g., sympathy). As a result of such tensions, scholars have described empathy as a multidimensional phenomenon 2, 4, 17]. We observed tensions akin to those identified by Cuff et al. [3] throughout our discussions. We conjecture that how one defines empathy plays a key role in the other tensions that arise and we thus begin our results section by discussing tensions evident in our dialogue defining empathy.

2.2 Tensions when Situating Empathy in Engineering

A little over a decade ago, few scholars had explicitly explored empathy in engineering [18], but recent years have seen exponential growth in such research. One prominent model of empathy in engineering comes from Walther et al. [1], who argued that how empathy manifests in engineering may be distinct from other professions. This idea suggests that empathy, as a concept, may not manifest the same way in engineering as in other professions. For example, engineers may often need to empathize with groups or society rather than individuals [1]. Thus, identifying whether empathy in engineering is primarily for an individual versus a group is, in of itself, one potential tension that is relevant to the engineering education and engineering design communities. There are also potential tensions regarding variable perceptions of empathy's importance to the engineering profession. For example, some engineering students view empathy as valuable in engineering, but the same students can simultaneously view "empathy as outside engineering" [19, p. 12]. Potential factors that influence or inform tensions regarding how empathy ought to manifest in engineering include individual perceptions of the role of empathy in engineering, including identity questions on what it means (and does not mean) to be an engineer, the post-positivist epistemological bias of many engineers, and (often) the distance between engineers' and the stakeholders of engineered works [5]. Taken together, the exponential rise of research on empathy in engineering over the past decade, the contextual ways that empathy manifests in distinct contexts [17], the potential for disagreement across scholars in this community [10], and the nascency of operationalizations of empathy in engineering design contexts [20] are each key motivations for this study's CI.

2.3 Situating Empathy in Engineering Design

Empathy is a salient component of engineering practice; however, literature lacks a consensus on how best to integrate opportunities to learn and practice empathy in the context of engineering [1, 5] and engineering design [6, 8, 21]. In recognition of competing conceptualizations of empathy, Kouprie and Sleeswijk Visser [8] argued for better-defined and structured tools and techniques for designers to use to meaningfully empathize with users and to better understand the user experience. In turn, Kouprie and Sleeswijk-Visser [8] offered a four-phase model of empathic design, where the designer enters and engages in another's world through phases of (1) discovery, (2) immersion, (3) connection, and (4) detachment. Hess and Fila [6] similarly offered an empathic design model, which was composed of 12 empathic techniques spanning four design steps: (1) developing empathic understanding, (2) identifying user-centered criteria, (3) generating design concepts, and (4) evaluating design concepts. While Hess & Fila [6] explored an immersive design context, Fila et al. [19] expanded this model. they identified additional techniques when students did not interact with users – thus, their findings aligned with Davis's [4] organizational model of empathy which suggested that situational cues can prompt how empathy manifests or which empathic techniques student uses. As a specific example, in Fila et al. [19], design students utilized "empathic manipulation" while engaging in a non-immersive design task, but this same task was not identified in the authors' prior work with students engaged in an immersive design task [6]. Similarly, Surma-Aho et al. [21] adapted Davis's [4] organizational model and identified antecedents and outcomes of empathic design processes. They found four high-level categories of antecedents (evidence-based perspective-taking; anticipatory perspective-taking; empathic concern; personal distress) and four high-level categories of outcomes (cognitive project-related learning, cognitively motivated project behavior, affective project-related learning, and affectively motivated project behavior). These brief examples show fundamentally distinct approaches and outputs of empathic design models for engineers, but each focuses on how empathy manifests in design in fundamentally distinct ways. Our study was thus also motivated by the divergence and nuances presented in these models of empathy, including those focused on empathy, in general [e.g., 4], models of empathy in engineering, writ broadly [e.g., 1], versus models of empathy in engineering design [e.g., 21].

3. Methodology

3.1 Conceptual Framework

In this study, we focus on tensions regarding empathy in engineering design as experienced by design instructors. Scholars have contrasted tensions with problems [10]. Problems connotate there is a potential solution; thus, one can fix problems. However, tensions may not have resolution and involve at least two areas of challenge which are often in competition or acting as opposing forces. While not always welcomed by engineers or others, tensions can be positive, which some authors have referred to as "productive tensions" [e.g., 22]. For example, in engineering education, a long running tension exists between the academic and scholarly goals of an engineering degree and preparation for professional practice [23]. Tensions have been the subject of research across many areas of education [24, 25], design [11, 12, 26], engineering education [13–15, 27, 28], and empathy [3].

Throughout this body of work, scholars have identified or addressed tensions through a range of approaches. Some work has looked at the evolution of tensions historically, such as Edstrom [23] who analyzes the historical roots of the tension between academic and industry or professional practice orientations in engineering education, while other work explored tensions in research or practice, such as Steen's [12] position paper that situated how tensions manifested across six human-centered design approaches (e.g., codesign and empathic design). Yet other works empirically examined the contemporary tensions within a research area [14, 15, 28]. For example, Morgan, Davis & Lopez [14] explored how engineering students navigate the process of gaining political fluency and uncovered three major tensions in this process: (1) the need to solely dedicate their time to academic study or allowing time for political engagement; (2) favoring contributing to the public good or prioritizing private gain, and (3) politics as periphery to engineering or politics as central to engineering.

In the present work we use tensions as our conceptual framework [29] to empirically explore how tensions in empathy and empathy in engineering design manifest in engineering design classrooms. This approach acknowledges the complex nature of empathy in design and fosters the development of a model to support considerations in studying and teaching empathy across contexts.

3.2 How Did We Promote Sharing Perspectives?

In this study we followed a collaborative inquiry (CI) approach, wherein a group of individuals or practitioners acted jointly as researchers and participants to define, understand, and build consensus on difficult and complex topics or questions of interest. More formally, Bray et al. [9] defined CI as "a process consisting of repeated episodes or reflection and action through which a group of peers strives to answer a question of importance to them" (p. 6). CI, as a type of inquiry, seeks to explore and build understanding from the experiences and/or practices of the participant-researchers [30, 31]. CI groups may form around shared community or lived experiences, such as women of color addressing spirituality in their work [30]. CI groups may also form around a shared practice or profession, such as nursing managers looking to promote a more equitable work culture [30]. Educators have fruitfully employed CI to address several complex topics [32–34]. Likewise, engineering educators have used CI to examine research practice [e.g., 1, 13] and to examine intersections across teaching and research practice [35].

Our collaborative inquiry process began informally as part of an ongoing funded project where five research team members worked with 10 design instructors to create a research instrument that captures empathy across unique design contexts. In this project, the research team has been facilitating the co-creation of a contextually sensitive empathy instrument wherein design instructors ("collaborators") provided input, critiqued emergent findings, and offered guidance and perspective regarding the utility of findings to their unique contexts. The research team thus aims to collect, synthesize, and share collaborator insights in an ongoing and iterative manner. During initial co-creation workshops, tensions emerged both in how we discussed empathy, how individuals had integrated empathy's integration in engineering design, and challenges they faced when striving for such integration [36].

While co-creation workshops are intended to support the investigators in the design of a contextually-sensitive measure of empathy in engineering design [16], this collaborative inquiry was intended to create a separate but still formal space to engage in tensions which were *not* the concerted focus of the co-creation/instrument design work. The lead author (Schimpf) invited both groups, the research team and collaborator team, to participate in the CI. Eight members joined the CI including five members of the research team and three members of the collaborator team (refer to Table 1). As shown in the final column, some members consider empathy part of their primary research focus, whereas for others it is a secondary or auxiliary interest. For us, this means our team had a mix of those with a stronger research focus or a stronger practice focus to help widen our conversations and highlight potential tensions. All members of the CI team were participant-researchers, and our goal was to foster equal participation among all participant-researchers [9]. To avoid accidentally reestablishing the role differences from the larger project, the CI team's meetings have regularly returned to and discussed what the role of a participant-researcher means for us both individually and collectively.

Our CI group met six times to discuss and synthesize tensions in empathy and empathy in engineering design. We followed a divergent-convergent process [37] to discuss the topic. Our first

Table 1. Collaborative inquiry team members and their primary design courses and engagement with empathy research

Member	Design Context	Discipline	University	Empathy Researcher
Fila	Senior Design	Electrical and Computer Engr	Iowa State	Primary focus
Heikkinen Dodson	First-Year; Senior Design	Mechanical Engr	Lipscomb University	Auxiliary focus
Hess	Junior Design; First-Year	Interdisciplinary Engr	Purdue University	Primary focus
Godwin	Cornerstone Design	General and Chemical Engr	Cornell Univ.	Auxiliary focus
Goldstein	Cornerstone Design; Senior Design	Industrial and Systems Engr	Univ. of Illinois	Secondary focus
Sanders	Junior Design	Interdisciplinary Engr	Purdue University	Secondary focus
Schimpf	Senior Design	Engineering Science	Univ. at Buffalo	Secondary focus
Sleezer	Junior; Senior Design	Integrated Engineering	Minn. State Univ.	Auxiliary focus

meeting established a foundation and began to explore empathy in design. Participant-researchers responded to four reflection questions about how they addressed empathy in their engineering design classes, what goals they hoped to achieve, differences in their instructional practices compared to other faculty, and any tensions they had experienced in this space. In our collaborative inquiry meetings, we used pre-session reflections to discuss emergent tensions in empathy and engineering design through breakout groups and later in a large group. This first meeting resulted in a large set of initial potential tensions. To maximize participant-researcher contributions to analysis, we engaged in an iterative form of content analysis [38] and thematic analysis [39]. After the first meeting, two members (Schimpf & Fila) conducted a content analysis by reviewing the meeting's transcript and extracting any tensions that received more than passing discussion. They identified potential relationships between tensions and created a Jamboard with post-its representing tensions and distance between post-its representing the similarity or dissimilarity between tensions. Then in the second session the team responded to tensions identified in the first. This involved several rounds of reviewing the tensions individually and adding, extending, or modifying the tensions, followed by a group discussion to share and synthesize ideas (and, often, generate more post-it notes). Fig. 1 highlights part of the Jamboard on which the team collaborated. This session resulted in an expanded list of tensions and key attributes for each. These first two meetings were primarily divergent. The third and subsequent meetings focused on synthesizing the large body of tensions and discussion towards a goal of convergence, as described below.

For the third session, the facilitator created a survey to gauge what the group felt were the most important tensions to share with the broader community. These tensions came from the Jamboard and the facilitator's judgment on which tensions were discussed the most during the second session. The group reviewed the survey results together in session 3. As the group was discussing which tensions to focus on at this stage, multiple team members engaged in a thematic analysis of the tensions, proposing a categorical or "theme scheme" for grouping tensions (e.g., definitions of empathy, pragmatic considerations for empathy in teaching, the value of empathy, and how empathy manifests in students' actions and practices). One participant-researcher (Hess) proposed a model mapping tensions to key questions for design educators to consider in their classroom practice. Subsequently, another participant-researcher (Fila) merged these two approaches into the model shown in Fig. 2 (note: we unpack this model throughout the results section).

Sessions 4–6 focused on developing the model, converging on what results to share, deciding on writing tasks, sharing reflections on the model or CI process, and collaborative writing to develop, synthesize, and narrate insights. Each participant-researcher was involved in writing the results. To facilitate writing tasks, the first author (Schimpf) reviewed which tensions corresponded with which themes. Five of the themes had two or more tensions mapped to them, which suggested to the team that these themes were more prominent in our discussions. After this, participant-researchers selected one or more of these five themes to lead the writing effort, based on their personal interest and those themes resonance with their own experiences. All themes had at least two participant-researchers contributing to the section. Importantly, we chose not to write about all 10 themes. This afforded us the opportunity to thoroughly describe the themes with more apparent tensions among our team. This, however, does not indicate that the remaining themes were less important; rather, it only shows there were less tensions communicated by the participants during the CI.

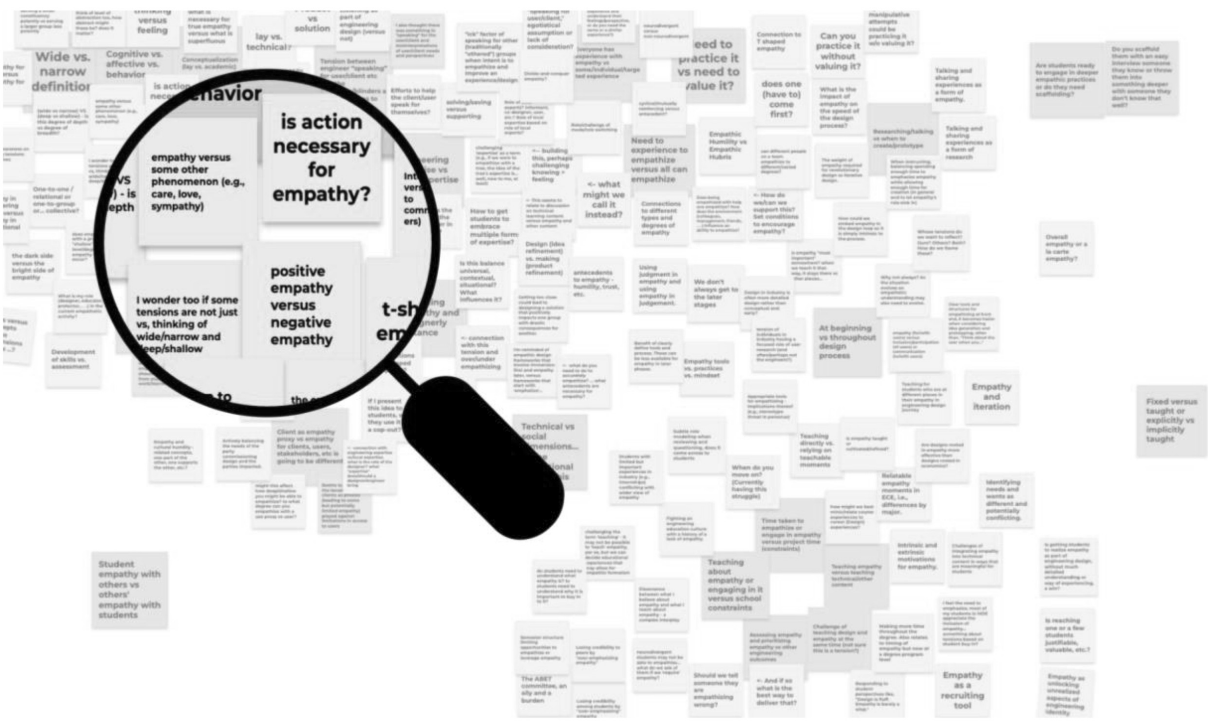

Fig. 1. The jamboard from divergent session 2 of the CI.

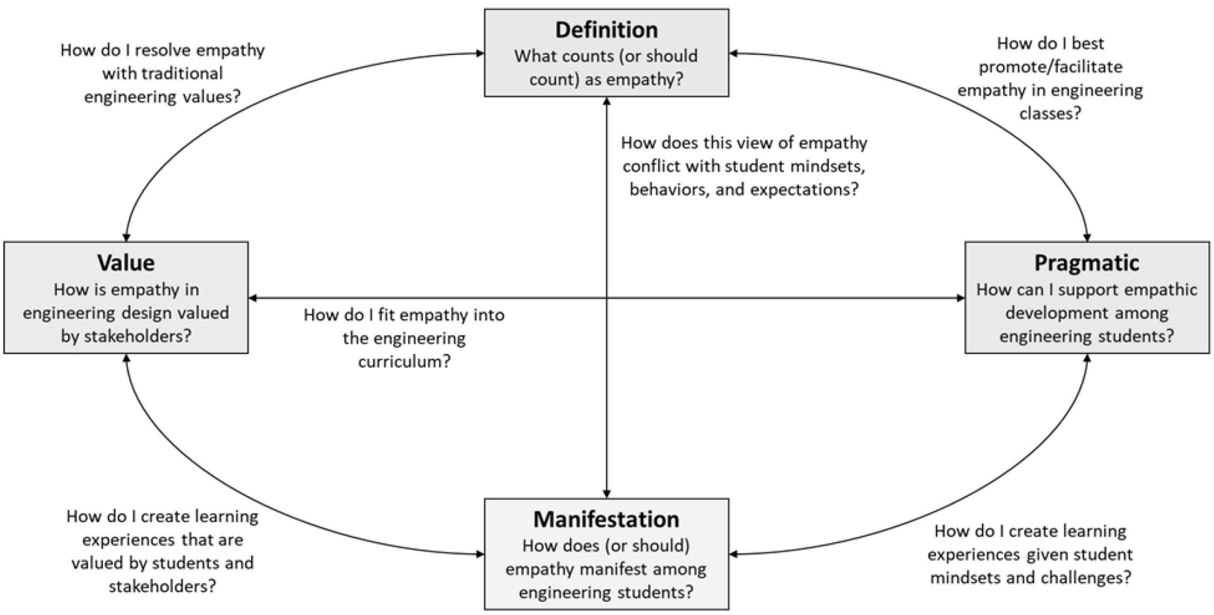

Fig. 2. Model of empathy tensions in engineering design education.

4. Results

This first stage in our collaborative inquiry resulted in a model that organizes tensions and describes the key ideas tensions address. The model consists of three components: (1) empathy frames, (2) intersections, and (3) tension considerations. In our discussion on how to present our findings from the CI, we ultimately decided to use an abstracted model or "theme scheme" to represent the tensions as we had many tensions to share. The theme provided a way to organize, relate, and communicate our ideas. Fig. 2 provides this theme scheme, where every question is associated with a theme in this study, as further described below.

Our first four themes we depict as *empathy frames* (definition, value, manifestation, pragmatic), and these frames grounded the model. Each frame represented how empathy was relevant to our teaching and scholarship in engineering design.

Table 2. Tension Themes, Descriptions, and Examples

Themes	Description	Tensions
Definition	How we do or should define or bound the concept of empathy, irrespective of design context.	Deep versus shallow forms of empathy
Value	How empathy among engineering designers benefits or resonates with stakeholder communities, including users, traditional engineering design culture, and others.	Technical vs. social prioritization
Manifestation	How empathy appears or occurs for engineering students.	Solving/saving vs. supporting
Pragmatic	How instructors support empathic development in real world contexts, amidst constraints, and within their own expertise.	Teaching empathy vs. facilitating an experience
Definition – Value	How values embedded in engineering culture might shape how empathy is defined and how a definition of empathy as connected to engineering practice (or not) may shape the value of that effort for engineering education.	Empathy at beginning vs. throughout design process
Definition – Manifestation	How ways of defining empathy do (and do not) resonate with students' lived experiences.	Authentic "failures" vs. inauthentic "successes"
Definition – Pragmatic	How ways of defining empathy influence what does (and does not) get taught in the classroom.	Integrating vs. spotlighting empathy
Value – Manifestation	How engineering values, stakeholder values, and student design tendencies and contexts intersect to form complex considerations of appropriate empathizing in engineering design situations.	Engineering expertise vs local expertise
Value – Pragmatic	How the value of empathy in engineering design can shape how it is incorporated into the curriculum.	Supporting empathic development vs. other learning outcomes
Pragmatic – Manifestation	How do instructors create learning experiences given students' pre-existing mindsets, instructors' challenges, and course constraints	Time to empathize vs. allotted class time

Tensions arose within these empathy frames through considerations of what is important in the frame or how empathy and related considerations were bounded. For example, the *definition* frame focused on the importance of understanding and bounding empathy, and undergirding tensions depicted distinct perspectives regarding how empathy is or should be defined.

Our second six themes we depict as *intersections* between *empathy frames*. Thus, these intersections represented the ways the empathy frames overlapped or interacted. Tensions typically manifested within their intersections when considerations in one frame competed with considerations in another frame. For example, the *definition-value* intersection focused on navigating how one might or should frame a definition of empathy given the value it can or should provide in engineering design processes or the practice of engineering, overall.

Third, each theme (both empathy frames and intersections) is signified by a question. These are the questions collectively addressed by tensions comprising the themes. Providing a thick description of each of the 127 tensions was not feasible within the scope of this work. Rather, in Table 2, we list each theme with key example tensions. Thereafter, we unpack the five themes most prominent in our discussions and the most salient to our experiences as engineering design educators interested in empathy. In taking this approach, we attempt to navigate a dissemination tension between providing detailed and clarifying descriptions while also demonstrating the breadth and content of our discussions.

4.1 Definitions (D): What counts (or should count) as empathy?

Definitional tensions abound in fields outside of engineering [2, 3], and it was (at least for us) unsurprising that we discussed tensions in defining empathy throughout this CI process. Tensions that we identified and grouped to this theme included (1) Cognitive vs. affective vs. behavioral empathy; (2) Deep vs. shallow forms of empathy; (2) Lay versus academic conceptualizations of empathy; and (4) Thinking vs. feeling. We describe the first two tensions in this section due to their prominence in our discussions.

4.1.1 Example D Tension 1: Cognitive versus Affective versus Behavioral

Our team discussed the role of cognition, affect, and behavior while discussing empathy in design. This discussion aligns with Clark et al. [17], who offered three "dimensions" of empathy: cognitive, affective, and behavioral. Yet, in this opening tension, we would argue that we are dealing with *two* tensions described by Cuff et al., including (1) cognitive or affective? and (2) does empathy have a behavioral outcome? We unpack these two ideas in turn.

First, recognizing one tension within this tension (i.e., cognitive or affective?) may imply that empathy *at least* has a cognitive or affective component -

whether that cognition or affect is primary or leads to an outcome is a separate point of contention and is taken up in the next paragraph. Some individuals in this inquiry (and scholars beyond this inquiry) seem to prioritize cognitive or affective empathy or, at the very least, recognize one dimension as dependent upon another. For example, de Wall (2009) offered a "Russian doll empathy model" that argued emotional contagion (an affective empathy type) precedes sympathetic concern (another affective empathy type) which precedes perspective-taking (a cognitive empathy type). Notably, members of our team also feel that "true empathy" requires both cognitive processes (e.g., role-taking) and affective experiences (e.g., empathic distress), and that behavior is an outcome of cognitive/affective empathy working in tandem – the behavior is *not* empathy.

Second, considering behavioral empathy, we hearken to Clark et al. [17] who defines behavioral empathy as "demonstrations of cognitive and affective empathy" (p. 167). This definition, however, does not necessarily specify behavior as *necessary* for empathy. Yet, a question might nag one whilst considering *empathy in engineering design* in light of this tension – why empathize if not to realize a certain behavioral outcome? In this spirit, during our CI sessions, one sticky note explicitly asked, "Is action necessary for empathy?" Here, we hearken to Davis [4], who offered an organizational model of empathy that culminates with intrapersonal and interpersonal outcomes – thus, behavioral outcomes are part of the model of empathy. Despite this, Davis's model does not depict one "right" way to empathize but rather depicts different possible pathways for empathy's manifestation – for example, one might generate intrapersonal outcomes (e.g., an understanding of a user) and still *not* act upon their understanding.

4.1.2 Example D Tension 2: Deep versus Shallow

Deep versus shallow empathy was oft discussed in our collaborative inquiry. Yet, even with this tension, we face the prior tension (affect versus cognitive versus behavioral). This tension might be interpreted in light of the question, "To what extent should students empathize with users?" Here, we hearken again to Davis [4], whose organizational model of empathy identified both simple and deep modes of empathy. Specifically, Davis differentiated between "simple cognitive" processes of empathy (including classical conditioning, direct association, and labeling) and "advanced cognitive" processes of empathy (including language-mediated associations and role-taking). Davis did not prescribe the "best" way to empathize but simply recognized different ways by which empathy may manifest.

Davis's processual orientation may (at least on the surface) emphasize the cognitive and neglect the affective. However, a certain level (or depth) of affective empathy may be needed to spark cognition (e.g., de Waal's Russian doll model) or to encourage behavior. For example, Hoffman [41], argues the observer must internalize a certain depth of empathic distress for them to react or respond to another; insufficient depth leads to a lack of helping, and, conversely, *too much* empathic distress can stymie behavior [41].

In the notion of *teaching* empathy to engineering designers, we referenced Fila et al. [19], who found that students in non-immersive design experiences seemed to focus on shallow understandings of users, which often were either self-oriented in nature (e.g., considering one's self in others' shoes) or general (e.g., "broad and superficial, perhaps to capture the complexity of the unspecified user group", p. 1343). Yet, such generalizations may lack empathic accuracy or be inapplicable to select user groups. This debate on deep versus shallow directly translates into the next theme, Pragmatic-Manifestation.

4.2 Pragmatic-Manifestation (P-M): How do I create Learning Experiences given Student Mindsets and Instructor Challenges and Classroom Constraints?

This intersection reflects a tension between how we think empathy should manifest in engineering design contexts and how we can pragmatically support students' development of empathic practices. At large, this tension is exemplified by the question: "How do I create learning experiences given student mindsets, instructor challenges, and classroom constraints?" Our discussions revealed two primary tensions here: (1) the time it takes for students to meaningfully experience empathy compared to the time students have to complete their design projects; and (2) understanding the degree to which *every* student in a team must deeply engage in empathy for students to understand the role of empathy in engineering design. Largely, these tensions were undergirded by curricular constraints (e.g., predetermined project timeline, limited class time, workload considerations), student team dynamics, project management, and the design processes that students utilized.

4.2.1 Example P-M Tension 1: Time to Empathize vs. Allotted Class Time

Building relationships with users, clients, and other stakeholders within the context of students' design projects takes time which is, itself, often timeconstrained (e.g., a semester). This challenge is further exacerbated when stakeholder groups are situated in contexts or have key characteristics with which students may be unfamiliar. Meaningfully engaging with and cultivating a deep understanding of these stakeholders or stakeholder groups requires significant time and effort (e.g., interviews, observations, and feedback sessions). However, students are often tasked with enacting a "complete" design process, from needfinding to prototyping, within the bounds of one course. As some of us considered what empathy looks like in the engineering classroom context, we felt a tension between the amount of time that educators can offer for relationship building and engaging in empathic practices versus other course outcomes, such as practicing technical skills, design skills, and other course deliverables. In addition to students building relationships with users, clients, and other stakeholders, design course instructors usually must engage in substantive pre-work to develop relationships prior to student-stakeholder relationship-building (e.g., identifying, contacting, and coordinating with potential project clients, users, or other stakeholders).

As a result of the course curricular constraints and demands, some of us felt that the myriad design tasks that students are asked to complete during one design experience resulted in the focus of empathetic practices being contained early in the design process (e.g., needfinding), rather than integrated and supported throughout the entire process. Moreover, given the variations in feedback and communication from stakeholder to stakeholder, students' design progress will be impacted, further complicating the challenge of ensuring students have opportunities to practice empathy before moving into the latter phases of design, which may have fewer well-demarcated opportunities for empathizing. Given the constraints of course curricula (e.g., course length), we were left pondering the following questions: During a design project, when should students move forward with making design decisions? Should they have limited communication with stakeholders? Is it "okay" for students to design for groups that are more easily accessible or that they might share more similar characteristics with such as fellow classmates? Can students empathize with a user proxy, or empathize in other ways besides direct communication with a stakeholder they have infrequent or no communication with?

4.2.2 Example P-M Tension 2: Select Deep Engagement with Empathy vs Lighter Engagement for More Students

As stated above, empathizing with users, clients, and other stakeholders takes dedicated time, which is limited within courses. Following this, some of us discussed a tension between providing students the opportunity to engage in deeper realizations of empathy (i.e., knowing this may not be possible for all students) versus supporting more students to have opportunities to use some empathy in a lighter or more limited way. For example, we contemplated possible approaches like half of a student team conducting interviews and engaging in deeper forms of empathy, with the other half of the student team completing other design tasks. As design instructors, we know student teams "divide and conquer" design tasks to balance their commitments to the project along with other course and life commitments. While ideally all students engage in empathic practices, unless there are specific requirements and allotted time, realistically, only some students will likely engage in empathic practices. Thus, we see a middle ground between this tension: while ideally all students would practice empathy in the context of design, some of us believe that pragmatically, we should strive to ensure that a critical mass of students engage with empathy during the design process. Thus, we understand that not every student will practice empathy as deeply as we hope and, with this in mind, we ask: "What "degree" of empathy is a realistic, baseline goal for all students to achieve?," and "Might students with fewer opportunities to empathize with users and other stakeholders be able to learn from students who practice empathic engagement more often?" For those who aspired to foster deep engagement with empathy, the next tension becomes especially salient.

4.3 Pragmatic-Value (P-V): How do I fit empathy into the Engineering Classroom?

In this theme, we uncover the tensions between prioritizing empathy in engineering design with other outcomes and within the constraints of academia. Simply put, how does empathy fit into engineering design curricula (pragmatic)? Also, why is empathy valuable in engineering design (value)? These questions expand upon similar tensions described previously while also delving deeper into the challenges of incorporating empathy into engineering design curriculum such that it provides significant value to the course, project, and student learning outcomes.

Traditional engineering outcomes tend to avoid social and behavioral skills and qualities, as evidenced by the emphasis on theory and concept knowledge in most engineering textbooks. Cech [42] describes this separation of skills in engineering as a technical/social dualism, or an ideological distinction between technical and social engineering subfields and work activities. If empathy in engineering design is seen as a social or behavioral product, where does it fit into traditional engineering outcomes? And does it provide sufficient value to engineering design such that it should be incorporated? If yes, how?

4.3.1 Example P-V Tension 1: Supporting empathy Development vs. other Engineering Learning Outcomes

Through the group sessions, discussion arose around many difficulties of teaching empathy alongside traditional engineering outcomes. Many of these challenges have been described already in the two previous sections, but a few others will be pointed out here. One aspect of this tension we discussed was teaching empathy directly and explicitly (like how most engineering outcomes are taught) compared to allowing empathy to come out of unplanned experiences or moments. For example, while instructors might be able to describe empathy and define it in a lecture, it is very challenging to practice empathy in engineering design in a classroom setting. Providing opportunities to interact and connect with stakeholders may be a solution, but these experiences are not easily constructed by faculty and require some flexibility and openness from both the students and stakeholders. Though challenging to integrate into a project, having true stakeholder involvement can improve the design and encourage student engagement at a deeper level, thereby leading to a stronger overall project. In some ways, when we effectively incorporate empathy into our engineering design curriculum, we could provide opportunities for deeper learning of more traditional engineering outcomes.

Another aspect of this tension we discussed included limitations regarding incorporating empathy in engineering design curricula. Other engineering faculty have noted the tension between teaching for technical abilities and professional skills [43, 44] and the tension between teaching for engineering formation and personal growth [45]. Many (if not most) engineering faculty were not trained in design with empathy in mind. Thus, for most faculty, empathy may be unfamiliar and uncomfortable to teach. Additionally, faculty may be restricted on what or how they teach certain courses due to department requirements.

Because empathy in engineering design may be unfamiliar or simply a newer topic, there are also limited resources (i.e., textbooks) for those who would like to incorporate these ideas into their courses. Interestingly, engineering textbooks have expanded over the years to include more professional topics like ethics, communication, and teamwork. Could empathy be included next? Accrediting agencies for engineering programs (e.g., ABET, European Network for Accreditation of Engineering Education, etc.) have defined "engineering design" by listing many topics that seemingly could incorporate empathy very well (e.g., accessibility, marketability, usability). If the primary resources and governing bodies for engineering programs incorporate empathy in engineering design explicitly, it is likely that faculty and students will follow this leadership, thus identifying novel ways to integrate empathy in engineering that have not yet been tried and tested.

We posit that incorporating empathy in engineering design will improve project outcomes and student engagement with the content. Building on this latter idea, empathy could be an avenue to provide a purpose to engineering design, thus influencing a student's identity development as an engineer. This connection could be vital for students who struggle with math and science and feel unqualified to continue in the major in light of these obstacles. This may also be a differentiating factor for students who excel in math and science but have struggled to find a connection to serving humanity through engineering. Overall, empathy in engineering design could be a path to increasing recruitment and retention for engineering programs by supporting such students' identity development.

Though not a source of discussion (or tension), the group sessions predominantly revealed or suggested the positive effects of empathy in engineering design. Practitioners in the group frequently mentioned that design products are improved by any incorporation of empathy into the engineering design process, such as with respect to ethics, feasibility, and sustainability. We also posited that improvements would be made in student skills like communication, teamwork, and conflict resolution. Others mentioned a shift from a 'hero' mentality as an engineer toward humility or simply getting students out of their comfort zones to create growth opportunities. The positive views regarding empathy in engineering design of this group may serve as a tension with colleagues who do *not* perceive empathy as a positive addition to engineering curriculum. We take the stance that such additions are valuable, thus leading directly to the next tension.

4.4 Manifestation-Value (M-V): How do I Create Learning Experiences that are Valued by Students and Stakeholders?

This intersectional theme represents tensions that manifest as students design for and engage with users. Tensions in this theme respond to three oft-competing elements. Regarding the Value tension, two of these elements are (1) traditional engineering values and approaches and (2) authentically and responsibly engaging with users in engineering design. Regarding the Manifestation tension, (3) the final element is how students empathize with users during engineering design and how such empathizing is, or should be, affected by those two value elements. The interplay between these three elements is evident in one key tension: engineering expertise vs. local expertise.

4.4.1 Example M-V Tension 1: Engineering Expertise vs. Local Expertise

Engineering design is one of the key places students both learn and demonstrate key engineering competencies [37]. These competencies include but are not limited to identifying and addressing complex sociotechnical problems, applying technical expertise to a challenging problem, teamwork and project management, systems thinking, analytical thinking, and valuing the human side of engineering. As students design with/for users, users' and other stakeholders' local expertise also becomes salient. This local expertise includes users' knowledge of their own contexts, cultures, and experiences. While engineering designers often cannot fully connect to local expertise, affective empathy may draw them closer to the individuals, communities, and cultures they are serving while cognitive empathy may create better awareness of others' values and challenges, as well as prompt their attention to how contextual factors may affect a design's feasibility, viability, and usefulness.

In any design context, engineering expertise and local expertise can work harmoniously to arrive at problem understandings and solution conceptualizations beyond what either engineering expertise or local expertise could create in isolation. However, conflicts can arise. In failing to consider or incorporate local expertise, engineers may arrive at technically proficient and highly functional solutions that do not sufficiently address user needs or that will be rejected by users for other reasons. Conversely, as engineers engage in local expertise through deep affective and cognitive empathy, they may lose sight of the value they can provide via technical, systems, and analytical expertise.

As students engage in engineering design projects, the above tensions still apply. However, their current level of professional development or values at the time of the project and desired development through the project can create an added layer of complexity. First, underdeveloped cultural competence or consideration of the human side of design can cause student designers to not fully engage local experts or fail to authentically engage their expertise in design work. Second, the desire to develop and demonstrate more technical elements of their engineering expertise may cause students to ignore local expertise. Conversely, students who deeply value local expertise may become over-distressed when project constraints or the constraints of their current engineering expertise fail to produce a valuable design solution for their users.

4.5 Definition-Value (D-V): How do I Resolve Empathy with Traditional Engineering Values?

This theme revealed tensions in how dominant engineering culture and norms may shape how empathy is valued in engineering education as well as how engineering values may shape what empathy means in engineering contexts. At its core, this theme is linked to axiological discussions of what is valued as engineering work and who decides. This intersectional theme explores how the definition of empathy is shaped by engineering values and how definitions of empathy in research and discussions of empathy in design may reveal underlying engineering values.

Research on engineering culture has described an emphasis on practical applications, where potentially abstract topics (like empathy) are only valued when taught in a practical, engineering-relevant context [46]. Engineering also views itself as meritocratic (i.e., talent and hard work are enough to succeed) and any inequalities are a result of mismatches in those skills and the demands of engineering [47]. Finally, engineering culture often separates the "rigorous" aspects of technical work from the "soft" components of engineering including communication, emotion, societal relevance, and empathy [48, 49]. It is with this cultural context that students can sometimes struggle to value empathy in engineering, even if they perceive empathy to be important to engineering design [5,19].

Three tensions emerged in our discussion including when empathy is leveraged (either at the beginning or throughout the design phase), wide versus narrow definitions of what counts as empathy, and the tendency of engineers to over- or under-empathize in design. In this paper, we focus on the first two of these tensions.

4.5.1 Example D-V Tension 1: Empathy at the Beginning vs Throughout the Design Process

Empathy is often emphasized in the early stages of design in needfinding but is also important in concept generation and evaluation of initial ideas [20]. It is often clearer to both students and instructors that input from those external to the project is needed at the early stages for design outcomes to meet the needs of stakeholders and address core criteria and constraints. Even in some CI participants' prior research, the development of a model for empathy focused on these three phases [20]. The tension was discussed in terms of if empathy was "most important" in particular places within design and whether an instructor's decision of where empathy is discussed may convey to their students an implicit valuation of where empathy is (and is not) connected to the design process. This tension also was discussed in how the definition of empathy is operationalized. Is it (1) for/with stakeholders or (2) the inclusion/participation of stakeholders or (3) communication to and with stakeholders? The answer to this question has implications for how empathy is engaged in the engineering design process.

The discussion of this tension raised questions of why empathy may or may not be the default for incorporation into engineering design, and emphasized a potential need for a deeper understanding of empathy's role within technical engineering work that might be currently disconnected from discussions of social dynamics and empathy in design. We grappled with the questions: How should empathy be engaged in the design process? Are there parts of the design process where empathy is "more important" or should it be engaged as a standpoint throughout the process? Do the ways in which engineering design in industry focus on detailed requirements and prototyping convey messages about the role of people in design? Are there particular tools that are more helpful for empathizing throughout design? Is empathy valued as a core part of design teaching and student development? Who decides where empathy is important and how does that reflect our values as engineers? Like most tensions, the more we grapple with this tension, the more questions arise (and, in turn, more potential tensions).

4.5.2 Example D-V Tension 2: Wide vs. Narrow Definitions of Empathy in Engineering Design

The definition theme highlighted the many elements and conceptualizations of empathy. Thus, empathy is a complex construct, even in a general sense (i.e., not specific to engineering design). When applying empathy to an engineering design context, these complexities persist and expand in response to what counts as empathy in engineering design [20]. The resulting discussion highlights a tension between a broad definition of empathy in engineering design and a narrow definition.

Many facets comprise the construct of empathy. Batson [2], for example, identified eight unique concepts that each lay claim to the mantle of empathy. Others have developed models of empathy that contain many disparate concepts. Davis's [4] organizational model of empathy consists of four themes: antecedents [to empathy], [empathic] processes, intrapersonal outcomes, and interpersonal outcomes, each of which contains several subcomponents. For example, within the empathic processes Davis describes are non-cognitive processes (e.g., motor mimicry), simple cognitive processes (e.g., direct association), and advanced cognitive processes (e.g., role taking). Do each of these components individually count as empathy? Does empathy require each of these components?

Our discussions of this tension focused on the above questions in the context of engineering design. Here, we focused less on reaching consensus on which components were required for empathy and more on the implications of considering a broader or narrower definition of empathy. A broader definition that includes many of the components acknowledges the variety of ways designers may resonate with users. It creates a lower barrier to entry for engineers. For example, engineering designers may experience simpler forms of empathy, or forms that rely more on assumptions about users based on limited information or their own experiences as opposed to deeper consideration of users' unique experiences, perspectives, and emotions. Such simpler forms of empathy may, in turn, support deeper, more authentic connections over time. A narrower definition ensures that what we call empathy is based in accurate and authentic resonance with users (albeit, 100% accuracy is likely infeasible, so another series of tensions may manifest when trying to discern how much empathy accuracy is needed). A narrower definition thus may reject the potentially harmful consequences of the more assumptive and self-centric concepts included in broader definitions, but it may also reject opportunities for designers to expand and develop from early, less authentic attempts to empathize with users.

5. Discussion

To guide this discussion, we asked each participant-researcher, "What is your key takeaway from the model itself?" and "What is your key takeaway from the process of building the model?" Highlights from our reflections included: (1) the model itself provides new instructional guidance and understanding of empathy and teaching; and (2) the process of collaborative inquiry was both challenging and enabled the team to create new connections and insights. We unpack these reflections here.

First, in terms of the model, several team members felt it provided a broader and deeper way to consider how instructions may bring empathy into engineering design classrooms. One key benefit participant-researchers mentioned was that the model highlighted potential tradeoffs an instructor must consider when managing or responding to these tensions. On this point, one instructor, who describe empathy as a secondary research interest, used the model to reflect on how they had relied on more general definitions of empathy in their class and, in turn, explicitly provided students with more time to interact with stakeholders when it took longer than originally anticipated. The team member noted these as tradeoffs in the definitional frame and between pragmatics and manifestation.

Other engineering education researchers have previously drawn on the engineering design concept of tradeoffs to provide a framework for addressing the highly open-ended nature and competing criteria that arise in course or project design [50]. This approach may likewise be applied when integrating empathy into engineering design curricula. Tradeoffs may provide a particularly powerful framing when dealing with tensions, as these have no singular answer or resolution [10]. Returning to our reflections, another team member noted that the model could serve as a strong starting point for other instructors (outside of this group or more generally) and provide a framework for them to reflect on how effectively they addressed their educational goals in their classroom.

Second, in terms of our process of building the model, the team reflected on the challenges and other new insights this CI project has helped unveil. One participant-researcher noted that the direction or goal of CI was sometimes unclear. In addition, another noted how divergent the discussions were at the beginning, which they felt added extra time to subsequent synthesis. This may partially stem from the flexible nature of CI as a research methodology that allows for multiple analytical approaches that span from practitioner-to-researcher oriented [9]. Turning to new insights, one member, who lists empathy as an auxiliary research interest, reflected on the similarities in tensions and where they arose for other team members, despite differences in our teaching and disciplinary contexts. Thus, although context affects our teaching practice, we believe that many tensions that we described will manifest (albeit, perhaps in slightly different ways) regardless of varying instructional contexts. Another member argued that the process demonstrated a way to hear and interweave multiple – and sometimes conflicting – perspectives. The same participant-researcher who listed empathy as an auxiliary interest also felt encouraged by the recognition that even those who list empathy as their primary research interest struggled with many of these tensions in their teaching.

This CI group took an inductive approach to identify tensions, although past research on tensions in engineering or empathy informed our inquiry processes. For many of the participant-researchers, past research on empathy and engineering design informed how they interacted with the group. Thus, despite our largely inductive approach, the model and tensions demonstrated clear connections to past and ongoing research on empathy.

Prior research has identified several challenges to empathic formation or growth in engineering students. For example, one challenge in promoting empathy for users or other groups, involves providing students with meaningful opportunities to access and interact with users. Another challenge stemmed from the fact that students sometimes question the applicability of empathy to engineering [19], which may reflect the culture of disengagement in engineering education [51] as one barrier to empathic formation. A related facet to these challenges is that engineering professionals often come to realize the importance of empathy to engineering work after spending many years in the profession post-graduation [52]. Taken together, these findings may suggest that empathy is counter-normative in engineering education and engineering programs, which can lead to challenges for instructors who aspire to promote empathic formation. We hope the model offered in this paper can help encourage instructors to move forward amidst the tensions.

6. Limitations and Future Work

We originally envisioned this paper and the resultant discussion at MDW as a way to solicit additional perspectives from the community about prevailing tensions with integrating empathy in engineering design education. Upon reflecting on the CI and this manuscript, we still recognize the need for several additional perspectives, including instructor perspectives in other contexts, scholar perspectives of those who study empathy in engineering (including, but not limited to, engineering design), practitioners in industry, students in engineering curricula, students in designing in teams (which has been arisen as a topic in our larger project, see [16]), and even views of community members. While our paper focused on instructors, these other perspectives will likely value different tensions, provide additional viewpoints on the tensions we have unpacked herein, and will likely generate additional sources of tension. We (and other scholars) ought to continue collaboratively inquiring into these tensions and incorporating more diverse viewpoints and perspectives. Finally, although we attempted to form a diverse group for our CI, we must acknowledge that our discussions and what resonated with the group was influenced by our experiences and backgrounds. Additionally, as we focused explicitly on the intersection of engineering design and empathy, related topics (e.g., ethics or sustainability) may not have emerged in our discussion as they were sometimes outside of our scope. Thus, this work should not be deemed representative of all tensions regarding empathy in engineering design. To that point, should another group of instructors engage in a similar CI, other tensions would likely have arisen.

7. Conclusion

Competing tensions focus on what empathy is, how instructors should introduce it in engineering curricula, and in what ways it may (or may not) be important to different stakeholders. These tensions can be productive, as we framed them in this work, but they also can become a source of contention and confusion for instructors, thus inhibiting or deterring one from prompting empathy in their courses or curriculum. We hope that the model we developed in this collaborative inquiry clarifies sources or points of tension and can help instructors become more confident in embracing their own approaches to empathic instruction. Furthermore, we suggest instructors and scholars use the model to specify their stances tensions when integrating empathy into engineering design courses and curriculum. Such clarity is needed to advance the space of empathy in engineering design forward with coherence and will ensure that scholars who follow after their predecessors can do so in ways that are congruent with said instructors' or scholars' perspectives.

Acknowledgements – We sincerely thank our team of collaborators who have participated in the co-creation activities and collaborative inquiry processes and have given significant insights, feedback, and support to this work. This material is based upon work supported by the National Science Foundation (NSF) under Grant No. EEC-2104782, EEC-2104792, and EEC-2104979. 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 NSF.

References

1. J. Walther, S. E. Miller and S. E. Sochacka, A model of empathy in engineering as a core skill, practice orientation, and professional way of being, *Journal of Engineering Education*, **106**(1), pp. 123–148, 2017.
2. C. D. Batson, These things called empathy: Eight related but distinct phenomenon. In J. Decety & W. Ickes (Eds.), *The Social Neuroscience of Empathy*, MIT Press, Cambridge, MA, pp. 3–15, 2009.
3. B. M. Cuff, S. J. Brown, L. Taylor and D. J. Howat, Empathy: A review of the concept, *Emotion Review*, **8**(2), pp. 144–153, 2016.
4. M. H. Davis, Empathy. In *Handbook of the sociology of emotions*, Springer, pp. 443–466, 2006.
5. J. Walther, M. A. Brewer, N. W. Sochacka and S. E. Miller, Empathy and engineering formation, *Journal of Engineering Education*, **109**(1), pp. 11–33, 2020.
6. J. L. Hess and N. D. Fila, The manifestation of empathy within design: Findings from a service-learning course, *CoDesign*, **12**(1–2), pp. 93–111, 2016.
7. C. Schimpf and J. Swenson, Reimagining faculty, student and community interactions in capstone: A synthesis of liberative pedagogies, citizen engineering and human-centered design, *IEEE Frontiers in Education Conference (FIE)*, Uppsala Sweden, October 8–11, pp. 1–5, 2022.
8. M. Kouprie and F. Sleeswijk Visser, A framework for empathy in design: Stepping into and out of the user's life, *Journal of Engineering Design*, **20**(5), pp. 437–448, 2009.
9. J. N. Bray, J. Lee, L. L. Smith and L. Yorks, *Collaborative Inquiry in Practice: Action, Reflection and Making Meaning*, Sage Publications, Inc, 2000.
10. R. Cheville and J. Heywood, From problem solvers to problem seekers: The necessary role of tension in engineering education. Paper presented at the *ASEE Annual Conference & Exposition*, New Orleans, LA, June 26th–29th, 2016.
11. C. R. Watkins, C. M. Gray, A. L. Toombs and P. Parsons, Tensions in Enacting a Design Philosophy in UX Practice, *Proceedings of the 2020 ACM Designing Interactive Systems Conference*, Eindhoven Netherlands, July 6–10th, pp. 2107–2118, 2020.
12. M. Steen, Tensions in human-centred design, *CoDesign*, **7**(1), pp. 45–60, 2011.
13. A. Kirn, J. L. Huff, A. Godwin, M. Ross and C. Cass, Exploring tensions of using interpretative phenomenological analysis in a domain with conflicting cultural practices, *Qualitative Research in Psychology*, **16**(2), pp. 305–324, 2019.
14. D. L. Morgan, K. B. Davis and N. López, Engineering political fluency: Identifying tensions in the political identity development of engineering majors, *Journal of Engineering Education*, **109**(1), pp. 107–124, 2020.
15. A. Van Barneveld and J. Strobel, Implementation of PBL in Engineering Education: Conceptualization and Management of Tensions, *Proceedings of the Canadian Engineering Education Association (CEEA)*, Hamilton, ON, August 7th, 2015.
16. J. L. Hess, N. D. Fila, C. Schimpf, A. Godwin and E. Sanders, A research study on assessing empathic formation in engineering design. Paper presented at *ASEE Annual Conference & Exposition*, Baltimore, MD, June 25–28th, 2023.
17. M. A. Clark, M. M. Robertson and S. Young, "I feel your pain": A critical review of organizational research on empathy, *Journal of Organizational Behavior*, **40**(2), pp. 166–192, 2019.
18. J. Strobel, C. W. Morris, L. Klingler, R. Pan, M. Dyehouse and N. Weber, Engineering as a caring and empathetic discipline: Conceptualizations and comparisons. Paper presented at the *Research in Engineering Education Symposium*, Madrid, Spain, 2011.
19. N. D. Fila and J. L. Hess, In their shoes: Student perspectives on the connection between empathy and engineering, Paper presented at the *American Society for Engineering Education Annual Conference*, New Orleans, LA, June 26th – 29th, 2016.
20. J. L. Hess, N. D. Fila, E. Kim and Ş. Purzer, Measuring empathy for users in engineering design, *International Journal of Engineering Education*, **37**(3), pp. 733–743, 2021.

21. A. Surma-aho, C. Chen, K. Hölttä-Otto and M. Yang, Antecedents and outcomes of designer empathy: A retrospective interview study, Paper presented at the *American Society of Mechanical Engineers' International Design Engineering Technical Conferences and Computers and Information in Engineering Conference*, Anaheim, CA, August 18–21st, 2019.
22. M. Klassen and J. M. Case, Productive tensions? Analyzing the arguments made about the field of engineering education research, *Journal of Engineering Education*, **111**(1), pp. 214–231, 2022.
23. K. Edström, Academic and Professional Values in Engineering Education: Engaging with History to Explore a Persistent Tension, *Engineering Studies*, **10**(1), pp. 38–65, 2018.
24. D. Schneckenberg, Understanding the real barriers to technology-enhanced innovation in higher education, *Educational Research*, **51**(4), pp. 411–424, 2009.
25. W. Hung, J. Harpole Bailey and D. H. Jonassen, Exploring the Tensions of Problem-Based Learning: Insights from Research, *New Directions for Teaching and Learning*, **95**(Fall), pp. 13–23, 2003.
26. J. E. Holt, D. F. Radcliffe and D. Schoorl, Design or problem solving – a critical choice for the engineering profession, *Design Studies*, **6**(2), pp. 107–110, 1985.
27. A. Godwin, Sitting in the Tensions: Challenging Whiteness in Quantitative Research, *Studies in Engineering Education*, **1**(1), p. 78, 2020.
28. K. D. Beddoes, Feminist Scholarship in Engineering Education: Challenges and Tensions, *Engineering Studies*, **4**(3), pp. 205–232, 2012.
29. A. J. Magana, The role of frameworks in engineering education research, *Journal of Engineering Education*, **111**(1), pp. 9–13, 2022.
30. L. Yorks and E. Kasl, Learning from the inquiries: Lessons for using collaborative inquiry as an adult learning strategy, *New Directions for Adult and Continuing Education*, **94**(Summer), pp. 93–104, 2002.
31. W. R. Torbert, Why educational research has been so uneducational: The case for a new model of social science based on collaborative inquiry, In P. Reason & J. Rowan (Eds.), *Human Inquiry: A Sourcebook of New Paradigm Research*, John Wiley & Sons, pp. 141–151, 1981.
32. J. Donohoo, *Collaborative Inquiry for Educators: A Facilitator's Guide to School Improvement*, Corwin Press, 2013.
33. T. H. Nelson, D. Slavit, M. Perkins and T. Hathorn, A Culture of Collaborative Inquiry: Learning to Develop and Support Professional Learning Communities, *Teachers College Record: The Voice of Scholarship in Education*, **110**(6), pp. 1269–1303, 2008.
34. K. Goodnough, Fostering Teacher Learning through Collaborative Inquiry, *The Clearing House: A Journal of Educational Strategies, Issues and Ideas*, **79**(2), pp. 88–92, 2005.
35. D. A. Delaine, D. Nabrit, N. L. R. Harris, C. Nabrit, C. Ratcliff and P. J. Penn-Nabrit, Factors that Promote Reciprocity within Community-Academic Partnership Initiation, *International Journal of Research on Service-Learning and Community Engagement*, **10**(1), 2023.
36. E. Sanders, J. L. Hess, N. D. Fila, A. Godwin and C. Schimpf, Co-creating a model of empathy in engineering design. Paper presented at the *Frontiers in Education Annual Conference*, College Station, TX, October 18th–21st, 2023.
37. C. L. Dym, A. M. Agogino, O. Eris, D. D. Frey and L. J. Leifer, Engineering Design Thinking, Teaching, and Learning, *Journal of Engineering Education*, **94**(1), pp. 103–120, 2005.
38. H. F. Hsieh and S. E. Shannon, Three Approaches to Qualitative Content Analysis, *Qualitative Health Research*, **15**(9), pp. 1277–1288, 2005.
39. V. Braun and V. Clarke, Using thematic analysis in psychology, *Qualitative Research in Psychology*, **3**(2), pp. 77–101, 2006.
40. F. de Waal, *The age of empathy: Nature's lessons for a kinder society*, Harmony Books, New York 2009.
41. M. L. Hoffman, *Empathy and moral development: Implications for caring and justice*, Cambridge University Press, Cambridge, UK, 2000.
42. E. A. Cech, Ideological Wage Inequalities? The Technical/Social Dualism and the Gender Wage Gap in Engineering, *Social Forces*, **91**(4), pp. 1147–1182, 2013.
43. S. Sheppard, A. Colby, K. Macatangay and W. Sullivan, What is engineering practice?, *International Journal of Engineering Education*, **22**(3), pp. 429–438, 2006.
44. E. F. Redish and K. A. Smith, Looking beyond content: Skill development for engineers, *Journal of Engineering Education*, **97**(3), pp. 295–307, 2008.
45. R. Aleong and M. H. Goldstein, Balancing curriculum design trade-offs for larger learning goals: An empirical study, *International Journal of Engineering Education*, **36**(2), pp. 556–567, 2020.
46. E. Godfrey and L. Parker, Mapping the cultural landscape in engineering education, *Journal of Engineering Education*, **99**(1), pp. 5–22, 2010.
47. A. E. Slaton, Meritocracy, technocracy, democracy: Understandings of racial and gender equity in American engineering education, In *International Perspectives on Engineering Education: Engineering Education and Practice in Context*, Volume 1, Springer, pp. 171–189, 2015.
48. S. Farrell, A. Godwin and D. M. Riley, A sociocultural learning framework for inclusive pedagogy in engineering, *Chemical Engineering Education*, **55**(4), pp. 192–204, 2021.
49. W. Faulkner, Dualisms, hierarchies and gender in engineering, *Social Studies of Science*, **30**(5), pp. 759–792, 2000.
50. C. Schimpf, Ş. Purzer, J. Quintana, E. Sereiviene and C. Xie, What does it mean to be authentic? Challenges and opportunities faced in creating K-12 engineering design projects with multiple dimensions of authenticity, In K. Sanzo, J. P. Scribner, J. A. Wheeler and K. W. Maxow (Eds.), *Design thinking: Research, innovation, and implementation*, Information Age Publishing, 2022.
51. E. A. Cech, Culture of disengagement in engineering education?, *Science, Technology, & Human Values*, **39**(1), pp. 42–72, 2014.
52. J. L. Hess, J. Strobel, C. R. Pan and C. Wachter Morris, Insights from industry: A quantitative analysis of engineers' perceptions of empathy and care within their practice, *European Journal of Engineering Education*, 2017.

Corey Schimpf is an assistant professor in the Department of Engineering Education at University at Buffalo. He was the Division Chair for the Design in Engineering Education Division (DEED) for the American Society of Engineering Education 2024 annual conference. His research interests include engineering and human-centered design, advancing research methods, and technology innovations to support learning in complex domains. He has a PhD from Purdue University in Engineering Education.

Nicholas D. Fila is an assistant teaching professor in the Department of Electrical and Computer Engineering at Iowa State University. He earned a BS in Electrical Engineering and a MS in Electrical and Computer Engineering from the University of Illinois at Urbana-Champaign and a PhD in Engineering Education from Purdue University. His research interests include empathy, ethics, design thinking, and course design in engineering education.

Justin Hess is an assistant professor in the School of Engineering Education at Purdue University. He earned his BS and MS in Civil Engineering and his PhD from Engineering Education, all from Purdue University.

Allison Godwin is the Dr. G. Stephen Irwin '67, '68 Professor in Engineering Education Research in the Robert Frederick Smith School of Chemical and Biomolecular Engineering at Cornell University. She serves as an associate editor for the *Journal of Engineering Education* and *Chemical Engineering Education*. Her research focuses on how identity, among other affective factors, influences diverse groups of students' experiences and pathways in engineering.

Elizabeth A. Sanders is a PhD Candidate in the School of Engineering Education at Purdue University. She earned a BS in Chemical Engineering from the University of Illinois at Urbana-Champaign and a MS in Higher Education from the University of Michigan. Her research interests include human-centered design in engineering, with a specific focus on empathy and interactions with users during the design process.

Kirsten H. Dodson is an associate professor and chair of the Mechanical Engineering department at Lipscomb University in Nashville, TN. Her research focuses on studying the connection between humanitarian engineering projects and views of equity and inclusion in the engineering workforce. Her background also includes research in thermal-fluids applications in mechanical engineering, specifically microfluidics.

Molly H. Goldstein is a teaching assistant professor and Product Design Lab Director in Industrial and Enterprise Systems Engineering at the University of Illinois. She earned a B.S. in General Engineering (Systems Engineering & Design) and MS in Systems and Entrepreneurial Engineering, both from the University of Illinois, Urbana-Champaign and her PhD in Engineering Education at Purdue University. Dr. Goldstein's research focuses on student design behaviors and actions.

Rob Sleezer is a faculty member at Twin Cities Engineering which is in the department of Integrated Engineering at Minnesota State University, Mankato. His role primarily focuses on facilitating learning in the project based TCE program. He earned his PhD in Microelectronics-Photonics from the University of Arkansas.