Toward an Integrated Framework of Empathy for Users among Engineering Student Designers

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Introduction

Empathy refers to how one understands, feels with, or reacts to others [1–3]. In engineering design, empathy manifests when a designer engages with user perspectives or experiences and uses this engagement to inform the design process [4]. By enabling designers to better understand users' needs or perspectives, empathy can lead to solutions that are more inclusive of and responsive to the issues users experience. Conversely, when designers do not empathize with users, their solutions are more likely to fail to address the problems they intend to solve [5].

Many recent design methodologies center empathy in the design process or situate empathy as an initial step in the design process [4,6–8]. For example, the d.School's five-part design model [8] starts with "Empathize" which they define as "the work you do to understand people, within the context of your design challenge" and the "effort to understand the way they [people] do things and why, their physical and emotional needs, how they think about [the] world, and what is meaningful to them." Other scholars have offered principles or beliefs to guide an empathic design methodology [7,9], wherein the principles span the entirety of the design process. Indeed, while Empathize is the first aspect of the d.School model, the team emphasizes an iterative and non-linear design process, highlighting the role of empathy throughout one's design process.

In the context of engineering, the ways in which empathy manifests within design may vary based on the goals of a design project or the phase of the design process. This study builds on our prior work establishing this theory with an instrument of empathy in engineering design based on testing with first-year engineering and multidisciplinary engineering students [10,11]. In this work, we seek to generate a better understanding of how empathy manifests in engineering design across a series of design phases and contexts. To achieve this objective, we share the unfolding of an *empathy in engineering design model* based on extant literature and our ongoing research with design instructors and students across a range of engineering disciplines. Throughout, we embrace an empathic design process as aligned with Mattelmaki and colleagues [7]. We seek to remain sensitive to the needs of humans (i.e., all stakeholders) by constantly asking "what if" questions, focusing on diverse user groups (i.e., students, faculty, users), engaging in purposeful and constant communication within and across user groups, and fostering a collaborative spirit, thus seeking opportunities for users to act as co-designers.

Literature Review: The Evolution of a Model of Empathy in Engineering Design

In this section, we focus on several key models and frameworks that focus on or are extensible to how engineering students empathize or how empathy operates within engineering design. This section serves as both (1) a literature review, highlighting relevant scholarship and situating this study within that scholarship, and (2) argumentation for a preliminary model of empathy for users among engineering student designers, which serves as the basis for the rest of the study. For each model, we provide (a) a brief overview of the model and any noteworthy extensions, (b) a description of how the model connects to or might help understand empathy for users among engineering student designers, and (c) what the model might not explain, including how exploring and integrating additional models might help. We note that none of the described models focus precisely on empathy for users among engineering student designers. Thus, item c should not be taken as criticism of prior work but rather limitations regarding the applicability of prior work in new or more specified contexts.

Walther, Miller, and Sochacka's Model of Empathy in Engineering

Walther and colleagues [12] developed a three-dimension model of empathy in engineering through interdisciplinary discussions. They guided the model through theoretical grounding from neurobiology, psychology, and social work and practical considerations of engineering. This model described empathy as a (1) learnable skill, (2) practice orientation, and (3) professional way of being. Walther and colleagues highlight several elements that define empathy within each dimension. For example, the *Empathy as a Learnable Skill* dimension incorporates affective sharing, self and other awareness, perspective taking, emotion regulation, and mode switching.

Walther and colleagues' [12] model provides a comprehensive way of viewing characteristics we might recognize among an empathic engineer and what learning/developmental goals we might target as educators. Moreover, the dimension structure provides a holistic perspective for integrating the many components of an empathic individual. As we focus on empathy for users among engineering student designers, two additional considerations occur. First, how does empathy manifest? In other words, what does it look like when students utilize their empathy skills, leverage their empathic orientations, or demonstrate their empathic ways of being? Second, what is unique about empathy for users in design? We begin to address the first question by highlighting a model of interrelated empathy constructs from Hess and Fila [13].

Hess and Fila's Framework of Empathy Types

Hess and Fila [13] described a two-dimensional framework for organizing the many constructs that have been described as empathy. For example, Batson [1] lists eight distinct "concepts" ranging from emotional contagion to perspective-taking to empathic distress. Hess and Fila's framework situates these empathy constructs on two-dimensions: affective-cognitive and self-other. The affective-cognitive dimension indicates that empathy can manifest as changes to one's emotional state as one feels for/with another (affective) as well as awareness, understanding, or consideration of another's thoughts, feelings, and experiences (cognitive). The self-other dimension indicates that these affective/cognitive experiences may be self-oriented or other-oriented. For example, in considering a user's perspective on a design solution, one might attempt to understand what the user experiences when using the solution (other-oriented cognitive empathy) or one might consider what they themself would experience if they were the user (self-oriented cognitive empathy). A final element of this framework is the concept of pluralism [3], which indicates that engineers may experience empathy types across quadrants based on previous or concurrent empathic experiences. Using the previous example, an engineer might first consider their own experiences with a solution (self-oriented cognitive) but then recognize differences between themself and the user and attempt to identify perspectives more aligned with the user's authentic experience, thus switching to an other-oriented cognitive empathy type.

This framework provides a framing device for instances of students empathizing with users that is flexible enough to cover a broad range of empathy types and specified enough to distinguish between empathy instances. It does not, however, address the specifics of the range of possible ways one's empathic skills, orientations, and ways of being might manifest in user design scenarios. To move toward this end, we shift focus to Davis' [2] organizational model of empathy.

Davis' Organizational Model of Empathy

Davis [2] applied a social psychological approach to address a generalized conception of empathy (i.e., not focused on engineering design or any other specific context). Through this approach, Davis developed a four-construct model consisting of antecedents, processes, intrapersonal outcomes, and interpersonal outcomes. In Davis' model, each of these constructs is connected, describing a general flow from contextual factors that inform empathy to outcomes of empathic experiences. The *antecedents* construct describes personal characteristics (e.g., biological capacities) and situational factors (e.g., observer/target similarity) that affect how/whether empathy manifests. One might consider the components Walther and colleagues [12] describe within this construct. The *processes* construct describes noncognitive (e.g., motor mimicry), simple cognitive (e.g., direct association), and advanced cognitive (e.g., role taking) processes that are consciously or unconsciously engaged in response to antecedents. These constructs then inform *intrapersonal outcomes* which consist of affective outcomes (e.g., empathic concern) and non-affective outcomes (e.g., attributional judgments) which align with the empathy types described by the Hess and Fila [13] model. Finally, each previous construct potentially informs *interpersonal outcomes*, which might be described as behaviors (helping, aggression, social behavior) resulting from intrapersonal outcomes.

Prior scholars have expanded Davis's functional model for discipline-specific contexts. For example, Gerace et al. [14] modified Davis's functional model for the context of nursing. Their analysis revealed how critical the central theme of "my role as a nurse-the role of my nurse" was as an antecedent to all other empathy types. This antecedent included perceptions about the inherent nature of empathy in nursing versus the need to balance empathy with professional obligations as a nurse. Thus, nurses' perceptions of this central question played a large role in informing all later empathic processes. Hess, Strobel, and Pan [15] explored engineering practitioners' conceptualizations of empathy and the related phenomenon of care. Their qualitative analyses revealed that practitioners described empathy in four related, but unique, ways: (1) as a perspective-taking act or "seeing the world from another's perspective"; (2) as imaginatively embodying another's position; (3) as a general sense of connectedness to the broader social or natural environment; and (4) the cognitive and intrapersonal outcome of understanding another's thoughts and/or feelings (p. 220). Many of the considerations align with the phenomena Davis [2] described, but they did not provide a processual pathway between empathy types and outcomes.

Davis' [2] model and its discipline-specific extensions [14,15] demonstrate empathy as an integrated process that is supported by personal and situational factors. The model suggested that empathy can be described by internal processes and outcomes and may result in external outcomes. Moreover, antecedents and interpersonal outcomes may differ across contexts, resulting in different ways empathy might be observed and different facets that might be most critical to empathy's manifestation. Thus, for the next stop on our tour of empathy models, we explore Smeenk, Sturm, and Eggen's [16] Empathic Formation Compass.

Smeenk, Sturm, and Eggen's Empathic Formation Compass

Smeenk and colleagues [16] developed their empathic formation compass through a focus on providing a model that addresses empathy as a construct and process, supports reflection on design action, and focuses on designers' roles and design decisions. The empathic formation compass integrates several empathy and design models to create a more robust sense of a designer's experience of empathy in design. These models include Hess and Fila's [13] model of empathy types, Sanders and Stappers' [17] landscape of design research (which situates design research in mindset (from expert to participatory) and research vs. design leads), among others. The resulting compass situates designer actions and experiences among empathy types experienced, mindsets and research techniques applied, and frames of experience (designers' lived experiences, users' lived experiences, designers' work, and others' work). Smeenk and colleagues [16] demonstrate how distinct design actions on a single project or design experience manifest throughout the regions of the compass. Moreover, they demonstrate substantial movement along the compass from action to action.

The Empathic Formation Compass [16] does not focus on engineering design, yet it demonstrates how designers may experience different empathy types as they engage in design activities common to engineering design. For example, Smeenk and colleagues describe a case study through placement on the compass. In the case study, the designer experiences self-oriented cognitive empathy while generating a design concept. Consequently, they experience self-oriented affective empathy when evaluating the concept. Additional research on engineering design contexts also suggests different experiences of empathy at different design phases [4,17].

Summary of Prior Research

The prior work discussed in this section suggests that empathy is a complex construct with important ties to engineering and engineering design. While empathy may be a characteristic of an individual engineer through a variety of skill, orientation, and way of being components, its manifestation/application may vary across situations and contexts. This variation may be in the form which empathy takes (e.g., other-oriented cognitive empathy, self-oriented affective empathy) or how those distinct yet related forms manifest at different phases of the design process. As we move toward a model to describe and measure empathy for users among engineering student designers, we must better understand those different empathy types, the phases of the design process at which they are salient, and details of such empathy type-design phase pairings that are relevant across the diversity of engineering student design contexts.

Methods

This paper examines the development and revision of a model describing empathy in engineering design guided by the previous discussion. The model, while having broader research and teaching applications, will be used to create a contextually relevant instrument to measure students use of empathy with/for users during course design experiences and, potentially, their empathic formation. This paper introduces our iterative, continuous, and ongoing model development process with engineering design instructors and engineering students across engineering disciplines (e.g., mechanical, electrical, biomedical). Thus, the primary goal of this paper is to detail the *evolution* of a model of empathy in engineering design.

Throughout the model's development, we have engaged in an empathic design process [4,6,7] elaborated with co-design strategies [18]. Our process has been guided by three principles:

1. **Model development as an act of human-centered design** - While our model is research-based and grounded by extant theory and scholarship, it ultimately represents a product that we hope will be valuable to several user groups: engineering students (e.g., supporting their empathic formation), engineering educators (who may use the model to guide coursework/curricula or the resulting instrument to assess learning or achievement), and engineering researchers (who may use the model or resulting instrument to support their research aims). Thus, we are committed to empathizing with such users and leveraging such empathy to guide model development.
2. **Engaging users in appropriate levels of co-design** - We are engaging each user group (students, educators, researchers) throughout the development of the model. We have made efforts to reach the variety of potential users in each group, engage with them in ways that are authentic to their empathy-design contexts, and facilitate sufficient agency for each group as they interact with and help refine the model. Through this latter point, we leverage co-design principles by Sanders and Stappers [18] which suggest repositioning the roles of designer and user in alignment with the level of creativity/facilitation they require.
3. **Iterative design** – We have engaged in an iterative prototyping approach throughout the process, including several user design cycles, interdisciplinary collaboration on model adaptations, and identifying ways to support future engagements and applications. With each cycle, we learn more about the users' contexts, goals, and language (including how current iterations align with said contexts, goals, and language), which then informs how we approach users for future cycles.

We describe the process guided by the above three principles in four phases. While these phases are presented linearly, there has been iteration involved in each phase and there has been temporal overlap between the phase. Each phase represents interaction with a specific user group in a specific way, representing learning and developments from prior experiences across user groups.

The first stage of our study involved sharing the initial instrument design processes, and how we retroactively visualized the model after designing the instrument, testing the instrument with students, and ascertaining structural validity of constructs within the model.

The second stage involved conducting interviews with 19 students who participated in a biomedical engineering junior design course that focused on identifying a user need and potential solutions to explore and develop in their capstone design course. Here, students were interviewed with a focus on a single experience designing for users in their engineering coursework. These interviews further focused on the overall design experience, instances of considering or interacting with users during this experience, and perceptions of empathy in engineering design. These interviews provided a more general overview of perceptions of empathy.

The third stage of our study involved collecting data over the course of three co-creation workshops. To ensure that our design is contextually relevant, and grounded in (and thus, applicable to) a diverse set of design experiences, we took a co-creation (i.e., co-design) approach to collecting data from design instructor collaborators. Co-creation, or co-design, is a design process where the users are active (rather than passive) in the design process, bringing their expertise to the table during design activities (i.e., idea generation, and "knowledge development") alongside the designer who also brings their expertise as a designer (p. 12) [18]. Therefore, we incorporated the ultimate users of the instrument (i.e., design instructors) in the process of unpacking the constructs that the instrument will ultimately measure. Thus, across these three co-creation workshops, we engaged 10 design instructors in a series of activities designed to prompt their exploration of their conceptualizations of empathy, engineering design, and the relation between the two. Specifics about the co-creation workshop and our iterative approach to co-creation workshop design are detailed in our prior work [19,20]. Resultant data included transcripts and visual artifacts created on an online visual collaboration tool (Miro).

Finally, we explored the relevance of the model (and aspects of empathy for users that might not yet be captured) within students' experiences engaging with users during their educational design experiences. Thus, using insights gleaned from the instructors' experiences teaching engineering design, we developed a semi-structured interview protocol for interviews with engineering undergraduate students in the courses taught by the design instructors. The interview asks students to recount their engineering design project experience, discuss times when they engaged with users, and times when they empathized with users while situating their experiences in and critiquing the extant model (introduced approximately halfway through the interview). Unlike stage 2, here we bring a more direct focus on reactions to the emerging model of empathy for users in engineering design. Also, unlike stage 2 (which collected interview data from biomedical engineering students), we focused on an array of undergraduate engineering design experiences that differed by academic discipline, undergraduate year, university, and type of design experience. While data collection for this second stage is ongoing at the time of this writing (February 2024), we have currently collected 11 interviews with engineering design students with disciplinary affiliations in computer engineering, industrial design, electrical engineering, bioengineering, first-year engineering, systems engineering and design, and engineering leadership & innovation.

By triangulating these data collection and analysis efforts, we hope to cultivate a deep understanding of engineering student experiences in design projects. In turn, we will leverage findings to identify experiences empathizing with users that are not currently captured in the model and areas where the current model may be improved to better represent their experiences.

Results: Model Evolution through Four Stages

Stage 1: Instrument Design and Model Visualization

The model we explore in this paper was grounded in a psychometric instrument which measured three empathy types across three design phases. The motivation for developing the instrument involved trying to gather evidence regarding how students experienced empathy in engineering design. A four-part model of empathy undergirded the instrument, wherein we distinguished between four empathy types which varied along two dimensions: (1) self-versus other orientations and (2) cognitive processes versus affective experiences. The empathy types situated within the four quadrants included imagine-other perspective-taking (which was situated in the other-oriented cognitive process quadrant), imagine-self perspective-taking (which was situated in the self-oriented cognitive process quadrant, empathic concern (which was situated in the other-oriented affective experience quadrant), and emotion congruence or empathic distress (each of which were situated in the self-oriented affective experience quadrant). The reader will note that we situated *two* distinct types of empathy within the self-oriented affective experience quadrant at two different points in time [13,21]. This swap showed a shift or vacillation in our emphasis regarding which type of empathy was most important. In a more recent paper, we broadened our focus to the domains themselves [11], thus affording the opportunity to consider the essence of the domain rather than a specific type of empathy (refer to Figure 1).

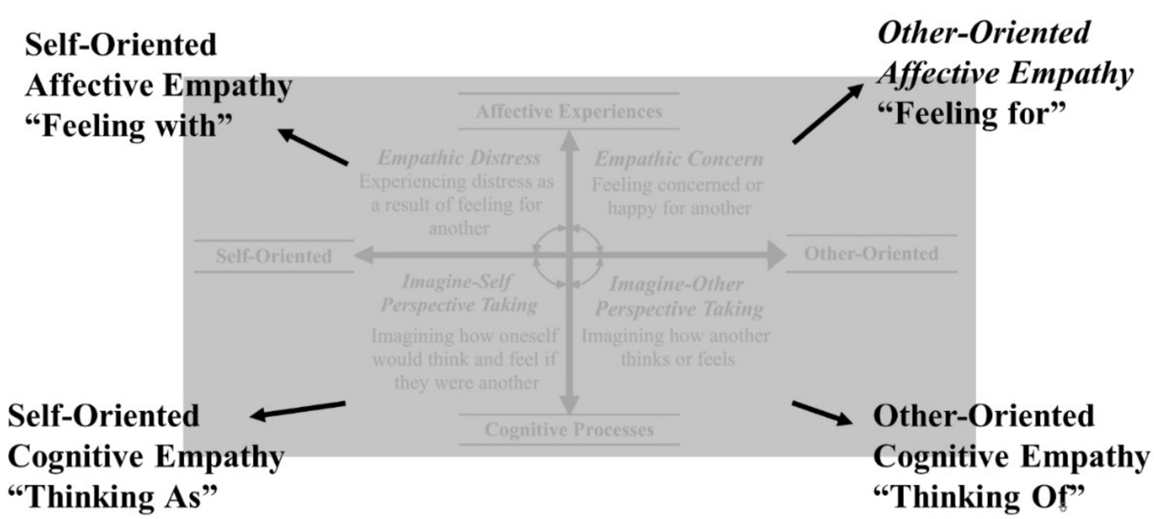

Figure 1: A revision to a two-dimensional model of empathy constructs (taken from [12])

In the prior instrument, we engaged in an expedited instrument development process guided by the empathy model and as part of an NSF RIEF Project led by a biomedical engineering faculty member. Two of the authors on this project who developed the empathy model (refer to Figure 1) provided input and guidance into the instrument development process but, given a need or desire to utilize the instrument with students shortly after the development process, we began testing what we now view as an initial draft of a measure of empathy in engineering design.

These initial implementations of the instrument afforded us the opportunity to test a series of empathy constructs in different configurations. Importantly, though, we did not capture all elements captured in the empathy model. Most notably, we combined self-other oriented affective experiences into a single domain, thus focusing on an overarching dimension we described as "Affective Empathy." Conversely, we developed items associated with "Imagine-Other" and "Imagine-Self" cognitive empathy, particularly (in this instrument) perspective-taking (as opposed to other potential types of cognitive empathy).

We tested measurement models where we accounted for how the empathy types manifested in design overall versus within specific design phases. We found reliable models in both instances, but the models that accounted for how empathy manifested in design phases exhibited superior model fit, which suggested that the empathy constructs manifested in unique ways across design phases. This finding motivated our further inquiry into other potential types of empathy and prospective design phases where empathy manifests in engineering design. Retroactively, to begin this discovery process, we depicted the measurement models as a model of empathy in engineering design, which is displayed in Figure 2. We are now seeking to develop a better understanding of how this model manifests in student and faculty experiences, as well as other prospective additions and components based on student and faculty data collection efforts.

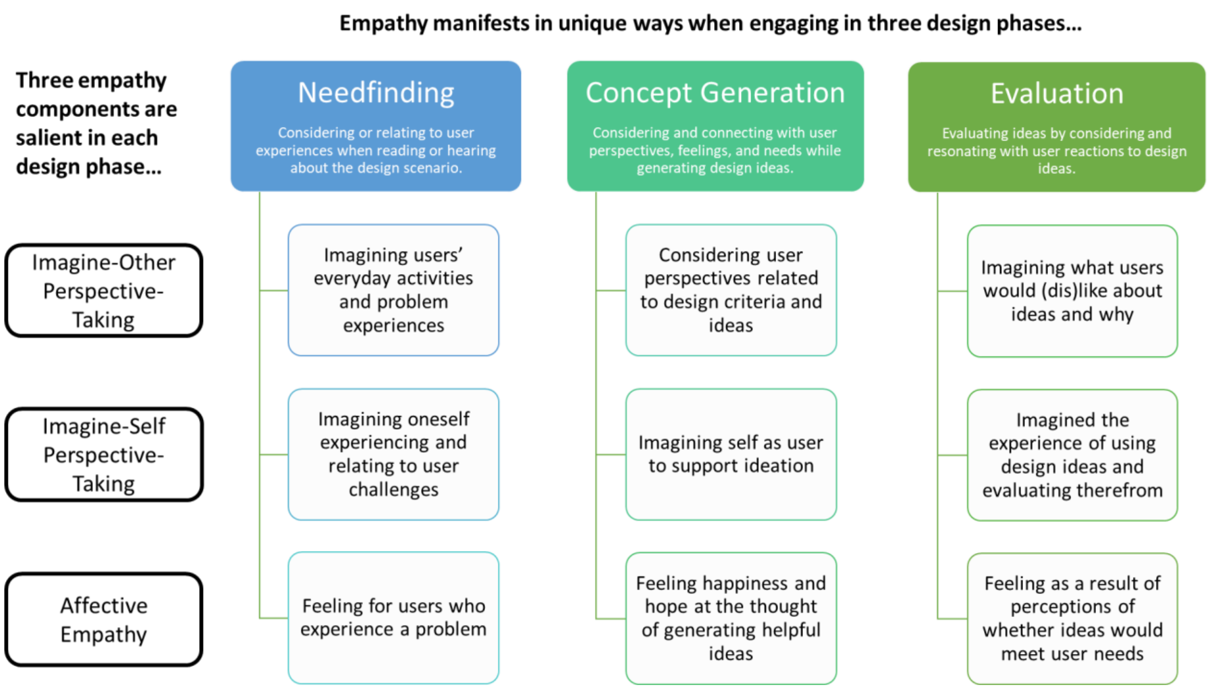

Figure 2: Initial model of empathy in engineering design (taken from [20])

Stage 2: Investigating Student Experiences through Critical Incident Technique

In this stage, we engaged in the critical incident technique [22,23] to explore the experiences of junior-level biomedical engineering students in the early phases of designing for a variety of user groups. Critical incident technique focuses on identifying and describing key elements of a process or type of experience. In the case of this study [17], we focused on the types of incidents that comprise the process of empathizing with users within the engineering design process. We focused on a specific population engaged in a specific type of design process to be able to explore nuances and consistencies not available in a broader or more representative sample. From in-depth, semi-structured interviews regarding students' experiences designing for users, we identified critical incident types that described the manifestation of empathy for users in the participants' engineering design processes. Critical incidents included (1) a framing of the personal or contextual factors that informed an experience with users, (2) a detailed account of an experience interacting with or thinking about users and therein developing empathy, and (3) a clear outcome related to the design process. We provide an overview of key themes below (Table 1).

Table 1. Themes from Critical Incident Technique Study

CIT Finding	Description	Implication for Model
Needfinding, concept generation, and evaluation highlighted critical incident themes	Among the six categories describing critical incidents, three categories, respectively, focused on experiences in the three design phases of the model. However, the specific design experiences described in the categories expanded upon the types of activities described in the model.	Further evidence for the connections between empathy and needfinding, concept generation, and evaluation. Potential for expanding the definitions of each to be more related to the experience of empathizing with users.
Criteria setting as a critical incident theme	Criteria setting joined the other three design phases as a critical and distinct mode of empathizing with users.	Should consider criteria setting as a distinct design phase in the model
Variation in empathy types	Observed empathy across self-other and cognitive-affective dimensions. Empathy manifested differently across and within design phases.	Empathy types add nuance to types described in current model. May need to address additional or more precise empathy types.
Relational empathy theme	In addition to design phase-empathy pairings, several critical incident types focused on building relationships and deep understanding of users in ways that informed the design process without directly affecting activities associated with any one design phase.	Aspects critical to empathy's formation may need to be included in the model, such as relationship-building or immersion within users' contexts.

Stage 3: Engineering Design Faculty Co-Creation Workshops

During this stage, we explored the empathy model through a series of co-creation workshops with engineering design faculty who teach in different majors (e.g., mechanical, biomedical, systems and industrial), at different regions of the US, and whose students range from first-year to their final year of their undergraduate engineering programs. These meetings were held virtually to accommodate all participants. We intentionally recruited instructors involved in different fields of engineering and at different grade levels in order to capture a more comprehensive understanding of how empathy for users manifested across these contexts. Each of the workshops followed the same general structure, wherein there was a pre-reflection activity to prepare instructors for the session, the core content of the session, and a post-reflection activity to capture any additional key insights or synthesis that participants did not share during the session.

We have conducted three co-creation workshops. The first workshop focused on instructors discussing their understanding of empathy, how it manifests in their instructional context, discussing differences and similarities across participants, and co-creating a model of empathy in engineering deesign. The second workshop had participants identify incidents where a student empathized with users via the creation of sticky notes in Miro, exposed participants to our empathy model (refer to Figure 2), and had them discuss where their sticky notes did or did not fit within the existing model. For more information on the first two co-creation workshops, please see [20]. The third workshop had instructors collaboratively create a persona of a highly empathic student and then identify a series of design moments their persona and their fellow participants' persona might face. In turn, participants co-created journey maps reflecting how they envisioned their persona would respond to the design moment.

Of the three workshops, the second and third provided more insights relevant to the model. In the second workshop, how instructors mapped their empathy experiences from students onto the model revealed several insights. We used the concept mapping tool Miro to set up a space where instructors could do this, which included spaces for experiences that did not fit on the model. While instructors were able to relate many of their identified student experiences to parts of the model, the distribution across the model was not always even. One instructor noted that there were considerably more experiences in the upper left-hand side of the model (i.e., imagine-other perspective taking in needfinding), although the distribution was different in the second round of the same workshop with a distinct set of participants. Participants described additional design phases not included in the model, such as immersion into the problem or with a user group as well as post-project construction or implementation. For one of the groups, several experiences did not map to the model. Participants also raised questions about the negative impact of empathy (e.g., a savior complex, generating unwanted results), thus identifying ideas regarding the potential negative role of empathy in engineering design.

For the third workshop, the design moments identified by instructors revealed similar and unique insights for the model. While several of the moments could be classified or categorized under the existing design phases of the model, others had no clear home or association. For example, several moments reflected late-phase design communication, such as when a team needed to share their results with a client or broader audience. Another type of moment that appeared frequently were ones that involved some sort of iteration or repeating of part of the design process, such as a moment where the team had to redefine the problem or make a decision between pivoting or proceeding on their current design path. These iterative moments do not as much reflect a design phases, as iteration can happen through the design process [24], which raises additional questions about the scope or scale of how the model represents design, including which phases or activities ought to be explicit.

Stage 4: Interviews with Design Students from Multiple Disciplines

While this research is quite nascent, here we share emergent themes based on our discussions of the interviews as guided by two lead interviews and the other members of our research team.

First, during interviews, students observed the engineering in design model. All students felt aspects of the model were relevant to their course experiences, and some students shared that all aspects of the model were relevant. Indeed, students were able to describe course experiences (and, in some instances, non-course engineering design experiences) where all aspects of the model were present. It is important to note, however, that the most salient aspects of the model seemed to vary from student to student. For example, some students emphasized Imagine-Self Perspective-Taking (ISPT), whereas others emphasized Imagine-Other Perspective-Taking (IOPT). In one instance, a student that designed for two different user groups during their project indicated that their emphasis on IOPT and ISPT varied based on the user group; namely, one user group was less like themselves, and IOPT seemed more salient, whereas another user group was students in their major, and ISPT seemed more salient.

Second, in the design of our protocol, we purposefully provided students with a two-part definition of the term user and asked them to identify to what extent the definition aligned with their views. Most students agreed that the definition seemed appropriate, but at least one student questioned whether users are anyone who "interacts" with the design, whereas another student emphasized that there are others who may not be "users" who were important to empathize with. Namely, this latter student - whose team designed a device for de-shedding dogs - indicated that the "decision-makers" (i.e., dog owners or groomers) were the individuals who they were going to focus on while marketing their design. Through this discussion, this student noted that these decision-makers might also be users, although they did not seem to be the end users. This students' discourse was like many others, where exploring perceptions of "users" alone may be inadequate to capture their empathy for others who they empathized with during the design process. Moreover, students may design for multiple users, or even who the primary user they are designing for may shift over time. To return to this students' example, the initial user group their team considered designing for were owners who had multiple dogs; they next focused on owners with any dogs; and, finally, they focused their design on dog owners with dogs who shed.

Third, we explicitly asked questions to identify whether and how the empathy types manifested in students' experiences and if so, how. Through our discussions, we realized that some students neglected to articulate their emotions or struggled to verbalize elements of affective empathy. In part, we questioned whether the language we presented in the model itself seemed confusing. For example, affective empathy may have been a new term for students. We also posit that the self/other combining in the affective empathy construct (which is dissimilar to the perspective-taking construct as presented in the model, refer to Figure 2) may have led to confusion or lack of clarity. Importantly, at least one student shared that feeling "with/for" others was the appropriate framing, as for him, this seemed to be the quintessential essence of empathy. Moreover, we continued to question whether the framing of the intersecting bubbles (i.e., empathy-design phase pairings) may have led students to consider only positive or negative aspects of empathy. For example, our framing of affective empathy in needfinding names positive emotions, but negative emotions can also motivate the identification of user needs. A more neutral framing may have provided a more open mode of responding that did not bias the valence of students' thinking or responding to model interrogation questions.

Finally, like the empathy types, we purposefully asked students to consider the design phases and if they were representative of their empathic experiences during design. Importantly, we noted that context matters for whether/how empathy manifests. For example, one participant seemed to perceive empathy to be unimportant as portrayed in their curriculum, at least as they experienced it, but they felt that it would be extremely important in their future career. Many students identified the need to add one more design phase, such as a phase between existing phaes or even beyond evaluation. One student described a potentially novel phase between concept generation and evaluation as "thinning," thus representing the team's convergence towards a final design idea or set of ideas. Another student suggested adding a phase beyond evaluation that had a prototyping flavor. In short, students were drawing attention to aspects of their design experiences where empathy was salient that the model did not explicate.

Discussion

Empathic design is an emergent design methodology, which traces its inception back to at least the work of Leonard and Rayport [5]. According to Postma and colleagues [8], principles of empathic design include: (1) "balancing rationality in emotions in building understanding of users' experiences," (2) making "empathic inferences about users and their possible futures," (3) "involving users as partners" through codesign or related processes, and (4) promoting a multi-disciplinary ethos among the design team themselves. Indeed, these beliefs closely resemble the four offered by Mattelmäki and colleagues [7], which include (1) "sensitivity towards humans" by "making sense of people and their experiences and contexts," (2) "sensitivity towards design" by asking "what if" questions, (3) "sensitivity towards techniques" via purposeful communication, and (4) "sensitivity towards collaboration." In this study, we embraced what may be construed as an empathic design research approach to studying how empathy manifests in engineering design. We sought to build on an initial cross-disciplinary collaboration that led to an instrument measuring empathy in engineering design by visualizing the model undergirding the instrument, interrogating the applicability of the model based on student perspectives, and engaging students and faculty members in open-ended activities to explore empathy's manifestation both in light of and irrespective of the model. These experiences largely supported the extant model and constituent elements but suggest additional elements that bear future exploration and, thus, refinement of the model.

First, while each of the research stages provided further evidence for the salience of empathy in needfinding, concept generation, and evaluation, additional design phases in which empathy for users is salient emerged. These phases and the respective research stages where they were identified include: immersion/relationship-building (Stages 2 and 3), setting criteria (Stage 2), prototyping/solution space convergence (Stages 3 and 4), and design communication (Stage 3). As each of these potential phases is emergent and has been suggested through engagement with different user groups, future work will focus on both clarifying the role of empathy in each of the phases across contexts, identifying specific ways in which the design phase-empathy type pairings manifests, and assessing the overall relevance of these design phases (i.e., should they be included in the model?).

Second, engagement across user groups has prompted re-evaluation of the empathy types that should be included in the model. Stage 1 suggested merging self-oriented and other-oriented affective empathy types into a single construct. Both the broader conceptualizations communicated by educators and students from Stages 3 and 4, respectively, support this change. However, deeper consideration of latent meaning from these stages and direct student communication from Stage 2 differentiates between self-oriented affective empathy (e.g., feeling bad if one is unable to alleviate user suffering through a design outcome) and other-oriented affective empathy (e.g., expressing concern for user suffering and leveraging that concern as design motivation). Additional distinctions, including positive and negative valences of affective empathy (e.g., empathic joy vs. empathic distress) and differing gradations of cognitive empathy (e.g., considering generalized user experiences vs. deep consideration of a specific user's perspectives), have also emerged and suggest further investigation.

Finally, questions of "Who is the user?" have emerged across all stages. Some of these questions are direct, e.g., pondering who actually qualifies as a user as opposed to a different type of design stakeholder. Some of these questions focus on level of abstraction, e.g., focusing on a specific individual or a larger group. Some of these questions focus on differences in relatability to different user groups, e.g., designing for other students as opposed to groups with which student designers share few obvious similarities. The key questions to address here are whether differences in target user groups presents issues for applicability of the model across contexts and how differences in user definition (or interpretation thereof) might affect experiences of empathy. This question also leads into a consideration of whether the model should focus on users exclusively or integrate user-adjacent stakeholder groups.

We plan to address each of these three items as we continue engaging each of the user groups and refining the model.

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