Co-Creating a Model of Empathy in Engineering Design

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***Abstract*—This WIP paper describes the development, implementation, and preliminary lessons learned from co-creation workshops with engineering design instructors. Co-creation is a generative process to collect and integrate diverse perspectives and offers a novel approach to engineering education research. Empathy is also a relatively new concept in engineering education, but literature has shown empathy can lead to improved engineering design outcomes. The primary objective of our study is to use co-creation to develop a model that depicts how empathy manifests in engineering design. We engaged in co-creation with instructors at universities across the United States to generate a collective understanding of how empathy manifests across engineering design contexts, and we will use these findings to iterate on an extant empathy in design model. The model will inform instructional assessments and pedagogies for integrating empathy in engineering design, which will enable (1) instructors to understand the extent to which their students empathize in ways that instructors hope they will and (2) have needed strategies to respond effectively to promote empathy's use in design.**

Keywords—empathy, engineering, design, co-creation

I. Introduction & Background

Empathy is both an affective and a cognitive phenomenon and can have behavioral outcomes [1], [2]. Empathy enables engineering designers to build relationships with users [3] and understand users' needs or experiences [4], [5], which can improve design outcomes. Thus, empathic formation is critical to preparing engineering students to become informed designers. Yet, empathy is a relatively new area of scholarship in engineering education [6], and there are extant tensions regarding how engineering educators [7] or engineering design instructors [8] should integrate empathy into engineering. We argue that empathy is important in engineering design, as found in literature on empathy in engineering design.

A. Empathy in Engineering Design

Zoltowski et al. [3] identified empathic design as the most comprehensive way of experiencing human-centered design among engineering students. Here, empathic design includes developing "a very broad understanding of stakeholders beyond scope of project" but, perhaps more importantly, "interacting with users informally" [3, p. 46]. Thus, empathic designers value users' lived experiences beyond the design process alone. Kwok-Leung Ho et al. [5] similarly described "layers of an intersubjective process to achieve empathy," which included engaging in three empathic processes: "connecting-of, acting-into, and merging with" (p. 102), calling attention to different modalities of empathy's manifestation, each of which they argue can help designers better understand users' experiences.

Many scholars have offered models for situating empathy in engineering design. Kouprie and Sleeswijk Visser [9] proposed an empathic design framework that described four phases: (1) discovering the user's world, (2) immersing or wandering around in the user's world, (3) connecting with users, and (4) detaching from users to engage in design. Fila et al. [10] and Hess and Fila [11] generated a four-phase design model comprised of (1) "developing user knowledge," (2) "identifying user-centered criteria," (3) "designing concepts with users in mind," and (4) "evaluating design concepts with users in mind" [10, p. 1339]. Each design phase included "empathic techniques" designers used to empathize. These models draw attention to how designers can empathize with users, but the model is not necessarily grounded in – and thus relevant to – the experiences of design instructors across disciplines.

B. Study Overview

Our overarching project objective is "to provide the engineering design community with a contextually valid instrument for measuring empathy for users in undergraduate engineering design contexts" [12, p. 3]. We address three research questions via co-creation workshops:

1. How do engineering design educators describe empathy in the context of engineering design?
2. How do engineering design educators frame a model of empathy that applies across engineering design contexts?
3. To what extent are assessment items/measures (1) interpreted consistently across a diverse group of design instructors and (2) deemed applicable/useful for assessing empathic formation across engineering design contexts?

We engage in co-creation with design instructors as they are potential users of the model but also bring diverse disciplinary experiences. Co-creation is a design research method that leverages "generative ideation" to integrate perspectives across various users and stakeholders [13, p. 10]. Thus, through co-creation we aim to generate and facilitate the integration of users' perspectives. Our focus is understanding how empathy manifests across design contexts. As such, these users – whom we refer to collaborators in this study – are experts in their domains. Co-creation with experts provides an opportunity to develop a rich, community-based understanding of empathy across engineering design contexts. Moreover, a co-creation approach may result in a participant's changed perception of the role of empathy in their work. This work-in-progress study describes the outcomes of initial co-creation efforts.

II. Methods

A. Collaborator Overview

Collaborators included ten engineering design instructors from universities across the United States. Collaborators represented many disciplines, taught in various settings, and instructed diverse student populations. All collaborators aimed to introduce empathy in design in their disciplinary courses.

B. Co-Creation Workshop Overview

We developed three co-creation workshops to explore the meaning and integration of empathy in engineering design education. At the time of writing, we have conducted two workshops and plan for at least one more. These workshops aim to cultivate a shared understanding of empathy in engineering design across collaborators, and we will use workshop data to develop a model representing this shared understanding.

Before each workshop, collaborators reflected on questions that primed them for the co-creation activities. At the beginning of each workshop, collaborators shared their pre-reflection responses and asked questions regarding their peers' responses. Second, collaborators interrogated the concept of empathy in engineering design via a generative and collaborative activity. Finally, collaborators reflected on their experience during the activity and shared key takeaways from the workshop. After each workshop, collaborators completed additional reflections to document their workshop takeaways and new insights. We provided collaborators with two meeting time options to engage in each co-creation workshop to accommodate all schedules.

We took an iterative approach to workshop design. Each workshop built upon and responded to the previous workshop. We discuss how the findings from each workshop inform subsequent workshops in the Results section.

1) Co-Creation Workshop 1

The objective of the first workshop was to engage collaborators with conceptualizations of empathy and develop a shared understanding of empathy in engineering design. Collaborators responded to three pre-reflection questions and shared them at the start of the workshop. Second, collaborators responded to five who/what/why questions, such as, "With whom do you want your students to empathize in engineering design?" Collaborators synthesized their reflections and developed a model for empathy in engineering design. Figure 1 presents sample models from Workshop 1.

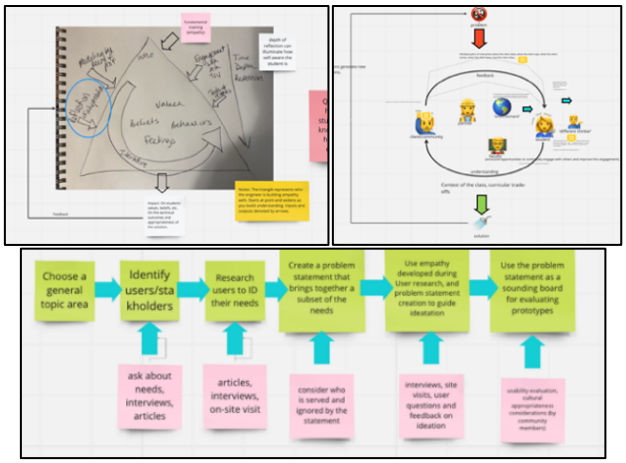

Fig 1. Example Models Developed During Workshop 1

2) Co-Creation Workshop 2

The goals of Workshop 2 were to (1) continue developing a shared understanding of empathy in engineering design and (2) interrogate an extant model of empathy in engineering design. In pre-reflections, collaborators documented a notable situation when a student empathized with users in a design project, listed other instances of student-user empathy, and described when student designers should empathize with users.

After sharing pre-refection responses, collaborators generated sticky notes using an online collaboration tool (Miro) to describe instances where students empathized with or for users. Next, they each shared one example of student empathy toward users they found most notable. Third, the research team introduced the collaborators to an existing model for empathy in engineering, informed by [14]. This model was reimagined to focus on empathy for users and provides examples of how different empathy types manifest across design phases (Fig 2).

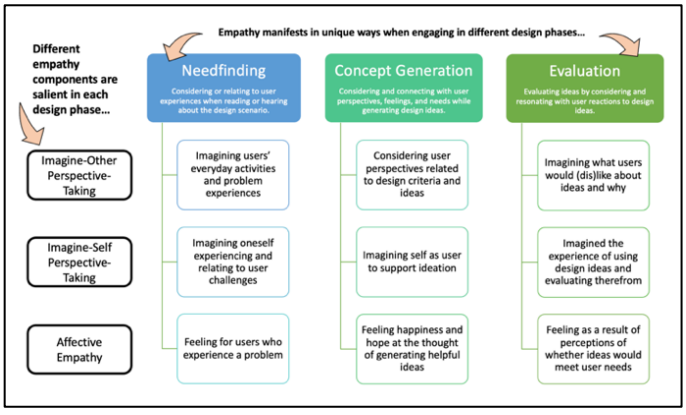

Fig 2. Model Presented to Collaborators during Workshop 2

Next, collaborators interrogated the model, and then we transitioned to the generative activity. We asked collaborators to review the sticky notes generated earlier in the workshop and map them to the presented model while considering questions like, "Does the sticky note (e.g., empathy instance) fit on the model?" and, if not, "Why not?" Through this activity, we encouraged collaborators to discuss unique manifestations of

empathy in their design contexts, which (we posited) might reveal empathy types or design phases not in the model.

C. Research Questions

We addressed two research questions: (1) Based on collaborators' perspectives, how does empathy manifest in engineering design?; and (2) How do emergent findings of RQ1 inform changes to subsequent workshops?

D. Data Collection

We collect three types of data in this study: (1) written reflections from pre- and post-workshop reflection prompts, (2) workshop transcripts, and (3) visual artifacts that resulted from the first two workshops. First, before and after each workshop, collaborators received a set of pre-reflection priming prompts and post-reflection follow-up prompts. Collaborators submitted these reflections to the research team. Second, the workshops (described in Section B) occurred on video conferencing software, were recorded, auto-transcribed, and reviewed for accuracy. Finally, portions of each workshop were facilitated on an online collaboration platform (Miro) so collaborators could generate text, images, and other visual elements to represent their ideas and complete activities during the session. Screenshots of the visual artifacts were captured for analysis.

E. Data Analysis

We engaged in an iterative thematic analysis that modified procedures offered by Braun and Clark [15]. Our data analysis had two goals: (1) to identify how empathy manifests in engineering design and (2) to improve the design of later co-creation workshops. We describe our approach to preliminary data analysis from Workshop 1 and Workshop 2.

1) Co-Creation Workshop 1 Analysis

Our analysis began by facilitating the workshops and documenting our observations throughout the session. After the session, all researchers immersed themselves in the transcripts and met to discuss their observations. Then, multiple researchers coded the transcript data with a codebook built from the extant model (Fig. 2). One author used co-creation Workshop 1 data to code for model components (Fig. 1). This author coded for empathy components irrespective of the design phase, observing that collaborators rarely portrayed how empathy manifested in design.

Collectively, we found that the model itself was not directly applicable to the data, which guided our (re)design of Workshop 2 to engage collaborators with the extant model and provide more structure for generative sessions. One researcher synthesized researcher notes and transcripts to generate preliminary themes. The same researcher narrated their observations in writing. A second researcher extended these data into themes. The research team then reviewed the themes for alignment with their session observations and experiences.

2) Co-Creation Workshop 2 Analysis

Like the Workshop 1 analysis, our analysis process began by facilitating the workshop and documenting our observations. Then, all researchers reflected on the sessions and met to discuss their observations. One researcher (Sanders) immersed themselves in the transcripts and researcher notes; synthesized these data; then narrated their observations in writing. A second researcher (Hess) refined and extended these data into themes. Next, the research team reviewed themes for alignment with their session observations.

Findings from this data analysis have informed our development of subsequent workshops. Moving forward, we will develop and implement coding scheme for all researchers to apply, informed by the preliminary analysis discussed here. Thus, we will continue iterating on the analysis process, in alignment with Braun and Clark [15]. This future analysis will inform an updated model of empathy in engineering design. Then, we will develop a quantitative instrument to measure contextually relevant empathy in engineering design across contexts, in line with the overarching project goal. We envision novel paths of research that can proceed parallel to this work.

III. Results

A. Emergent Themes from Co-Creation Workshop 1

We offer three themes from the first workshop from our preliminary analysis. These themes span two categories related to our goals: (1) building an understanding of collaborators' conceptualizations of empathy in engineering in design (i.e., developing the empathy model) and (2) better developing co-creation workshops to cultivate a shared understanding among collaborators and focus collaborators on the project goals.

1) Variation in Defining Empathy

Our first observation during Workshop 1 was that many collaborators offered competing views regarding what does (and does not) constitute empathy. Both groups discussed the differences between sympathy and empathy. This led to discussions about whether one can truly empathize with another person they do not share similar experiences with. One collaborator reflected on the differences between sympathy and empathy and how that related to lived experiences and shared:

> If you're going to be empathetic toward the situation or someone, did you have to have the same lived experience? […] I don't have any pets, but, and I don't prefer cats. But I had a student once, who was so attached to their cat came to class and started crying in front of me. And, it was the first time I understood why she loved her cat so much, you know, so I went from having sympathy for her, "Oh, I'm sorry to hear, you know, your cat sick" to "this person's really attached to their cat, you know, in a way that I would never experience." – *Sam*

Perhaps because of the variation in collaborators' conceptualizations of empathy, we found that we could identify the presence of the three empathy types included in the extant model (Fig. 1), but we also observed some members referenced and built on extant models (e.g., Walther et al. [2017]). Due to this variation, we aimed to have collaborators interrogate the extant model in Workshop 2 more purposefully.

2) Variation in Most Salient Empathy Targets

As collaborators discussed empathy in engineering design, they described several groups that students might empathize with, such as users, clients, stakeholders, professors, and

teammates. One collaborator felt there was value in adding these relationships into the model: "I think in our discussions we spoke about broader than a client student or client engineer relationship." Questions about who one should empathize with during design undergirded many workshop conversations.

While we encouraged explorations of empathy towards many groups (e.g., clients, stakeholders), our guiding objective is to develop an instrument to assess students' empathy with users. Accordingly, we sought to more purposefully focus activities during Workshop 2 on empathy for users.

3) Co-Creation Dissonance

We observed that the open-endedness of the model development activity was too broad for the time allotted. A collaborator in Group 1 noted their difficulty with this activity:

> Just want to wanted to note that I'm kind of more observing in this task, I think it's just very difficult. […] Because I know I questioned the extent to which, like an actual, we can actually develop, like a model here. - *David*

While collaborators discussed the value of co-creation as a generative exercise and presented a draft model(s) at the end of the workshop, the research team noted that it took encouragement to begin the collaborative activity.

4) Community

Collaborators shared grappling with the concept of empathy alongside one another was helpful. One collaborator shared:

> I think for me, maybe a, perhaps, 'aha,' [a surprise realization] perhaps, is getting to interact with people that are, I guess, some have practice doing collaborative work together. I definitely felt a bit on an island during the exercise making my little kind of flowchart, but then once I dropped it into the collaboration section, having people jump in and start adding to it really helped me see how what I was working towards actually can better integrate with what the big goal of the exercise was. – *Robin I*

Another expressed a desire for more collaborative interaction, as some collaborators approached activities individually.

B. Emergent Themes from Co-Creation Workshop 2

1) Extant Model Applicable to Empathy Instances

Largely, the collaborators shared that the presented model resonated with their understanding of empathy in engineering design. As collaborators mapped instances of empathy onto the extant model for empathy in design, most were mapped to imagine-other perspective-taking and early design stages. In the words of one collaborator who noticed, "it's still pretty obvious that most things [are] in the upper left corner." On the one hand, this may be because many design process models emphasize empathy during the early design phases. Moreover, design courses ask students to complete a prototype for their course deliverable, with limited opportunities for user engagement due to the short time frame (i.e., a semester-long design project). In this sense, others found evaluation, as framed in the model (i.e., Fig. 2), applicable in early design phases. Another collaborator shared: "If you separate out evaluation from the needs finding […] How do you go back and have that additional empathy [throughout the design process]?" They then referenced another collaborator's idea to answer their question: "you actually bring it back to the users and get that intermediate feedback."

2) Missing Ingredients

Collaborators found that some instances of empathy documented on sticky notes were not mappable to this model. Themes from the unmapped sticky notes included: overwhelming negative feelings (e.g., sadness) that may hinder design progress, design activities related to pre-project (i.e., project selection) and post-project (i.e., implementation), contextual or antecedent influences on empathy, transformational empathy, and team considerations. One collaborator shared, "This also doesn't necessarily get into some of the bigger contextual aspects. […] this [model's] focus is sort of on the users and individuals rather than what's informing their needs as well."

3) The Model as Pragmatically Useful

Multiple collaborators desired to use the model right away in their courses and curriculum. One collaborator shared, "I wish I had this with my students. […] If I was wise enough to do some steps like this, they would probably get there faster to where they eventually do." In general, the collaborators saw this model as a helpful tool to begin conceptualizing empathy, but as the "Missing Ingredients" theme captures, the collaborators felt there was room for improvement. In the words of one collaborator, "it's already useful. I imagine as it continues to evolve, it'll get sharper and sharper."

IV. Closing Discussion

This work-in-progress paper describes the development and preliminary analysis of the first and second co-creation workshops. We offer co-creation as a research approach in engineering education and we share how our initial data collection and analysis procedures informed iterations to subsequent workshops. Insights gleaned from data collected during Workshop 1 informed Workshop 2. We envision providing design educators with a revised, contextually validated instrument comprised of Likert-type response items and additional response styles (e.g., open-ended reflections). We hope such a measure will enable users to contextualize the measures, such as specifying with whom they would like to assess student empathy and which empathy types are important.

We envision this work will inspire novel research pathways. In this spirit, we have worked alongside a sub-set of collaborators to engage in a collaborative inquiry project to discern *tensions* that can lead to challenges or uncertainties in integrating empathy into engineering design [8]. In addition, we will continue incorporating emergent findings into our planning for future co-creation workshops. Based on the results from Workshop 2, one goal of Workshop 3 will be to further explore the Missing Ingredients alluded to herein.

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References

[1] M. S. Davis, "That's Interesting!: Towards a Phenomenology of Sociology and a Sociology of Phenomenology," *Philos. Soc. Sci.*, vol. 1, no. 2, pp. 309–344, Jun. 1971, doi: 10.1177/004839317100100211.

[2] M. A. Clark, M. M. Robertson, and S. Young, "'I feel your pain': A critical review of organizational research on empathy," *J. Organ. Behav.*, vol. 40, no. 2, pp. 166–192, Feb. 2019, doi: 10.1002/job.2348.

[3] C. B. Zoltowski, W. C. Oakes, and M. E. Cardella, "Students' ways of experiencing human-centered design," *J. Eng. Educ.*, vol. 101, no. 1, pp. 28–59, Jan. 2012, doi: 10.1002/j.2168-9830.2012.tb00040.x.

[4] A. Surma-aho, C. Chen, K. Hölttä-Otto, and M. Yang, "Antecedents and Outcomes of Designer Empathy: A Retrospective Interview Study," in *Volume 7: 31st International Conference on Design Theory and Methodology*, Anaheim, California, USA: American Society of Mechanical Engineers, Aug. 2019, p. V007T06A033. doi: 10.1115/DETC2019-97483.

[5] D. K. Ho, J. Ma, and Y. Lee, "Empathy @ design research: a phenomenological study on young people experiencing participatory design for social inclusion," *CoDesign*, vol. 7, no. 2, pp. 95–106, Jun. 2011, doi: 10.1080/15710882.2011.609893.

[6] J. Strobel, C. W. Morris, L. Klingler, R. Pan, M. Dyehouse, and N. Weber, "Engineering as a caring and empathetic discipline: Conceptualizations and comparisons," presented at the Research in Engineering Education Symposium, Madrid, Spain, 2011.

[7] J. Walther, M. A. Brewer, N. W. Sochacka, and S. E. Miller, "Empathy and engineering formation," *J. Eng. Educ.*, vol. 109, no. 1, pp. 11–33, Jan. 2020, doi: 10.1002/jee.20301.

[8] Corey T Schimpf *et al.*, "A collaborative inquiry into tensions between empathy and engineering design," presented at the Mudd Design Workshop, Claremont, CA, 2023.

[9] M. Kouprie and F. Sleeswijk Visser, "A framework for empathy in design: stepping into and out of the user's life," *J. Eng. Des.*, vol. 20, no. 5, pp. 437–448, Oct. 2009, doi: 10.1080/09544820902875033.

[10] N. D. Fila, J. L. Hess, S. E. Purzer, and E. Dringenberg, "Engineering students' utilization of empathy during a non-immersive conceptual design task," *Int. J. Eng. Educ.*, vol. 32, no. 3(B), pp. 1336–1348, 2016.

[11] J. L. Hess and N. D. Fila, "The manifestation of empathy within design: findings from a service-learning course," *CoDesign*, vol. 12, no. 1–2, pp. 93–111, Apr. 2016, doi: 10.1080/15710882.2015.1135243.

[12] J. L. Hess, N. D. Fila, C. T. Schimpf, A. Godwin, and E. A. Sanders, "A Research Study on Assessing Empathic Formation in Engineering Design,"

[13] P. Jones, "Contexts of Co-creation: Designing with System Stakeholders," in *Systemic Design*, P. Jones and K. Kijima, Eds., in Translational Systems Sciences, vol. 8. Tokyo: Springer Japan, 2018, pp. 3–52. doi: 10.1007/978-4-431-55639-8_1.

[14] J. L. Hess, N. D. Fila, E. Kim, and S. Purzer, "Measuring empathy for users in engineering design," *Int. J. Eng. Educ.*, vol. 37, no. 3, pp. 733–743, 2021.

[15] V. Braun and V. Clarke, "Using thematic analysis in psychology," *Qual. Res. Psychol.*, vol. 3, pp. 77–101, 2006, doi: https://doi.org//10.1191/1478088706qp063oa.