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Comparing Empathy Between Male and Female Undergraduate Engineering Students*

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This multiphase quantitative study explores variation in how male and female engineering students empathize. Phases 1 and 2 compare male and female engineering student responses to two empathy constructs: perspective-taking and empathic concern. Phase 3 explores differences based on post-course survey reflections representing how male versus female first-year engineering students perceived using empathy in their curricular design projects. Students were from a biomedical engineering program in a large urban university in the USA (Phase 1) and first-year engineering students at a large rural university in the USA (Phases 2 and 3). Results show that female engineering students reported greater empathic concern than male students. First-year engineering female students also reported greater perspective-taking tendencies. First-year female engineering students reported empathizing during engineering design projects to a greater extent than male peers, including both cognitive and affective empathy types. Taken together, findings suggest there is a gendered nature of empathy in engineering, and thus it is important for engineering instructors to consider variation between male and female students' use of empathy when seeking to foster it in their curriculum. When organizing engineering design teams, instructors may capitalize on the empathic strengths of female students to ensure effective stakeholder integration and responsiveness.

Keywords: empathy; engineering design; quantitative; gender

1. Introduction & Background

This study adds to a growing body of literature focused on empathy in engineering education [1–4]. Outside of engineering, empathy has been depicted as integral for compassion and altruism [5–7], helping to identify user needs in business contexts [8], moral development [9, 10], and prejudice reduction [11]. Within engineering, empathy has been depicted as critical to successful interpersonal relationships [1, 12–14], engineering design [15–17], and creativity or innovation [18, 19]. Thus, overall, empathy can help engineers better engage, relate to, understand, and engineer for/with/as others, including other users, clients, and stakeholders [20].

Hess and Fila [4] argued there were five areas in engineering education where promoting empathic formation would align with curricular goals or instructional strategies: (1) design thinking, (2) service-learning, (3) communication, (4) collaboration, and (5) ethics. While empathy may be applicable across these areas, challenges manifest when introducing empathy in engineering education, many of which are grounded in competing definitions of how students view engineering, how students view engineers should engage non-engineering stakeholders, and (in turn) how students view engineering education learning processes should unfold [1]. Due to such tensions, scholars have argued for fostering antecedent skills or dispositions to help students empathize, such as mindfulness [21] and civic-mindedness [22].

While prior to 2012, there were few engineering studies focused on empathy in engineering [2], recent years have seen rapid growth in this domain, especially in the context of design [4]. Empathic design exists as its own unique form of design with a unique set of principles [23]. Empathic design as a unique process has existed for more than two decades [8, 24] and in 2012, Zoltowski et al. [25] identified empathic design as the most comprehensive form of human-centered design. Students in this category sought to develop a holistic understanding of user needs and were committed to ensuring that their designs effectively met said needs.

Today, there are numerous models of empathic design, with one of the earliest generated by Kouprie and Sleeswijk Visser [26]. These authors offered a four-phase empathic design model comprised of discovery of, immersion in, connection to, and detachment from the user's life world. More recently, Fila and Hess [27] explored how empathy manifested in the design prompts of students engaging in a service-learning oriented human-centered design challenge (a tree house for students with limited mobility). They found that empathy supported four broad design phases: (1) developing user understanding, (2) identifying user-centered criteria, (3) generating design concepts, and (4) evaluating design concepts. Recent studies have developed similar process models of empathic design, thus

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substantiating the instrumental and unique role of empathy throughout engineering design processes and for realizing users' needs [28–33].

While empathy is important to engineering design, especially human-centered design [25], not all engineering students empathize to the same extent. One potential variable that informs the extent to which students empathize is gender, with female students often exhibiting empathic superiority [34, 35]. Davis [34], for example, found that females tended to exhibit more empathy, particularly along its affective dimension. This trend may hold in the context of engineering. For example, while Rasoal, et al. [36] found that engineers tend to exhibit less empathy than peers from psychology and social work, they also found differences in the extent to which male and female engineering students empathized. Given engineering is a male-dominated discipline, this suggests that seeking parity in male/female representation in engineering may also help reduce this empathy gap between engineering and non-engineering disciplines.

Marinelli and colleagues [37] explored how important Australian male and female engineers perceived empathy in their practice. They found that female engineers viewed empathy as more personally important and more valuable for responding to "potential impacts" than their male peers. Similarly, a recent qualitative investigation [38] found variation in how students empathically responded to animal subjects in a biomedical engineering lab, with many female students (and few male students) voicing affective concerns regarding animal subjects. Contrariwise, Hess, et al. [39] found that among practicing engineers, gender did not influence perceptions of the importance of empathy and care in their practice. There are few studies directly studying how empathy varies between males and females in engineering. As these few studies reveal contradictory results, there is a need to extend this line of investigation.

This study aims to generate a better understanding of how male and female engineering students empathize in engineering curriculums by quantitatively examining the extent to which empathy varies between male and female students at two US university sites. The study addresses three research questions (RQs):

RQ1: How does empathy vary between male and female biomedical engineering students at a large urban university in the Midwest USA?

RQ2: How does empathy vary between male and female first-year engineering students at a large urban university in the Midwest USA?

RQ3: How does empathy's utilization in design vary between male and female first-year engineering students at a large public university in the Midwest USA?

2. Conceptual Framework

This study's operationalization of empathy builds on the work of Davis [40], Clark et al. [41], and Hess and Fila [4]. Herein, empathy varies in terms of self/other-orientation and cognitive/affective dimensions [41]. Self- versus other-oriented cognitive empathy types vary in terms of one imagining oneself in another's shoes (e.g., "thinking as") versus imagining another in their own shoes (e.g., "thinking of"). Moreover, self- versus other-oriented affective empathy differs in terms of one internalizing another's emotional state (e.g., "feeling with") versus feeling some emotion based on one's interaction with another (e.g., "feeling for"). These quadrants comprise distinct empathy "concepts" [42] which are, themselves, distinctly measurable [36].

In engineering, when discussing empathy, scholars may (knowingly or unknowingly) emphasize the cognitive over the affective. For example, Niewoehner and Steidle [44] defined *intellectual empathy* as an engineering virtue, thus emphasizing the ability for one to *know* another's states rather than *feel* such states. Yet, affective empathy has been deemed critical for prosocial motivation [10]. With

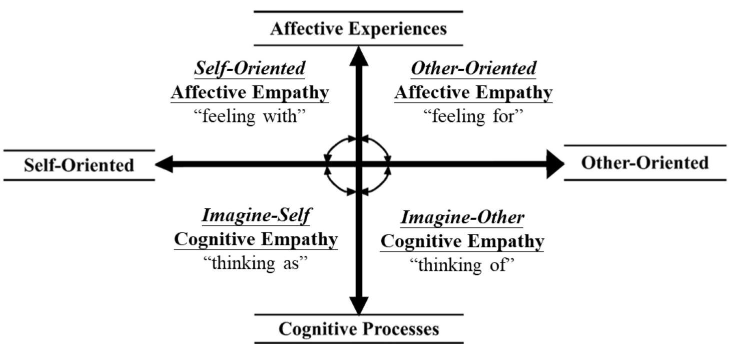

Fig. 1. Four-fold empathy framing [adapted from 43].

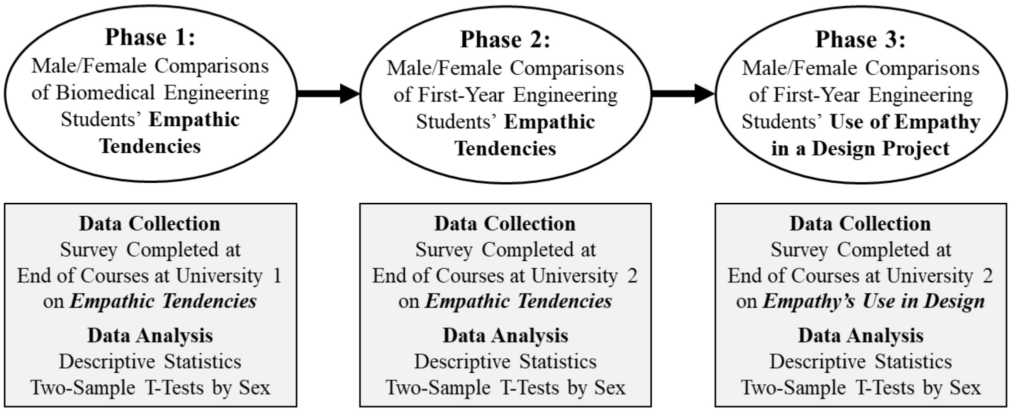

Fig. 2. Research Design.

this said, cognitive empathy may be dependent upon affective antecedents, as depicted in "affective primacy" models [10, 45].

Walther et al. [46] emphasized the import of "mode switching," or switching between affective and cognitive empathy dimensions. As they discuss, it is challenging (and perhaps impossible) to employ cognitive and affective empathy dimensions in unison and "it is therefore important for engineers to recognize these two facets of engaging in sociotechnical contexts to be able to purposefully modulate them" (p. 135). Similarly, Hess and Fila [4] (and later Hess, Sanders, and Fila [43]) depicted four empathy types and their representation emphasizes the cyclical relationship between concepts (see Fig. 1). In summary, multiple empathy types (or "concepts" [42]) exist, manifest distinctly, but should inform each other for empathy to manifest holistically.

3. Methodology

3.1 Research Design

This three-part study utilizes similar survey instrumentation but at distinct university sites, both in the midwestern United States. Each phase explores variation in male and female students' empathy. Phases 1 and 2 explores female students use of empathy, whereas Phase 3 explores females' perceived use of empathy in an engineering design project. Fig. 2 provides a graphical depiction of the study's three parts and their sequential unfolding.

The original purpose of data collection efforts at both sites was to study the impact of curricular efforts on students' empathic development and utilization. An emergent research focus on male/female comparisons resulted from qualitative data and analysis at University 1, which revealed variation in empathy among students [38]. These findings, coupled with prior studies indicating potential differences by gender [36, 37], served as the primary motivation for this investigation and this emergent research focus.

3.2 Participant Overview

This study includes participants at two large Midwestern US universities. The primary distinctions between sites are that (1) University 1 is urban whereas University 2 is rural and (2) the engineering student population (and choice of majors) at University 1 is much smaller when compared to University 2. In this study, students from University 1 include biomedical engineering students, whereas students at University 2 include students enrolled in a first-year engineering course. Each featured substantive representation of male and female engineering students, thus presenting sufficient sample sizes for comparing male/female responses.

Table 1 summarizes participants by University site. University 1, associated with Phase 1, included 111 biomedical engineering respondents and participants with higher-level academic standing (i.e., 52 seniors, 40 juniors, 19 sophomores, and 0 freshman). University 2, associated with Phases 2 and 3, included 419 respondents with lower-level academic standing (i.e., 390 freshman, 25 sophomores, and 3 juniors). At University 2, students do not declare their engineering major until the end of their first year, and thus these students' academic disciplines were largely undecided (both by students and the university) at the time of data collection.

Students at University 1 included near-equal representation by sex (i.e., 55 males and 56 females). In contrast, University 2 included 75% males (n = 312) to 25% females (n = 104); three students at University 2 specified another sex or declined to specify. Finally, participants' race/ethnicity at both sites were mostly White, although University 2 included approximately one-quarter Asian respondents. Finally, respondents from University 1 completed the survey at the end of an academic semester between Fall 2017 and Fall 2019. In contrast,

Table 1. Participant overview by university site

Description	University 1	University 2
Total Participants	111	419
Academic Standing		
Freshman	0	390
Sophomore	19	25
Junior	40	3
Senior	52	0
Not Declared or Unknown	0	1
Sex		
Male	55	312
Female	56	104
Other or Decline to Specify	0	3
Race/Ethnicity		
American Indiana or Alaska Native	0	2
Asian	5	117
Black or African American	2	12
Hispanic or Latino	2	28
Native Hawaiian or Pacific Islander	0	2
White or Caucasian	84	277
Multi-Racial or Other	5	2
Not Declared	6	10
Age (M, SD)	21.1 (3.0)	18.4 (0.60)

Note: At University 1, students with multiple racial/ethnic ethnicities were combined into a single "multi-racial" category, whereas at University 2, students may have selected multiple racial/ethnic categories; thus, the sum of the race/ethnicity responses at University 2 is greater than 419.

Table 2. Survey Items for Perspective-Taking (PT) and Empathic Concern (EC) – Note: Survey is from Davis [40] with adaptations by Hess et al. [47]

Construct	Item	Item Description
Perspective-Taking [40]	PT01	I sometimes find it difficult to see things from the "other guy's" point of view. (-)
	PT02	I try to look at everybody's side of a disagreement before I make a decision.
	PT03	I sometimes try to understand my friends better by imagining how things look from their perspective.
	PT05	I believe that there are two sides to every question and try to look at them both.
	PT06	When I'm upset at someone, I usually try to "put myself in his shoes" for a while.
	PT07	Before criticizing somebody, I try to imagine how I would feel if I were in their place.
Empathic Concern [40]	EC01	I often have tender, concerned feelings for people less fortunate than me.
	EC03	When I see someone being taken advantage of, I feel kind of protective towards them.
	EC06	I am often quite touched by things that I see happen.
	EC07	I would describe myself as a pretty soft-hearted person.

Note. Responses ranged from 1 (*Strongly Disagree*) to 9 (*Strongly Agree*).
(–) denotes worded items that were negatively worded and where scores were reversed prior to analysis.

respondents from University 2 completed the survey only at the end of the Fall 2019 semester.

3.3 Instrumentation

This section outlines the psychometric instrumentation used in this study. Phases 1 and 2 employed two constructs from the Interpersonal Reactivity Index [40]: empathic concern and perspective-taking. Empathic concern represents one's tendency to feel compassion for another; thus, it is an other-oriented affective empathy type. Perspective-taking represents one's tendency to imagine another's thoughts and feelings. Thus, perspective-taking represents an other-oriented cognitive empathy type. Fig. 1 represents where these items fit in the four-fold empathy model, and Table 2 includes survey items associated with these constructs. Importantly, based on factor analytic procedures conducted by Hess et al. [47], one item from the original IRI was removed from Perspective taking and three items were removed from Empathic Concern. Table 2 provides an overview of the

Table 3. Survey Items for Empathy in Engineering Design Constructs – Note: Constructs were developed and structurally validated in Hess et al. [48]

Construct	Item	*Preface:* Item Description
Imagine-Other Perspective-Taking (IOPT)	IOPT_01	*While reading or hearing about the design scenario:* I imagined the users' everyday activities within their real-life context.
	IOPT_02	*While reading or hearing about the design scenario:* I imagined how the users would feel when they experience the problem.
	IOPT_03	*While generating my design ideas:* I imagined what design criteria would be the most important to the users.
	IOPT_04	*While generating my design ideas:* I imagined how my ideas would look from the users' perspectives.
	IOPT_05	*While evaluating my ideas:* I imagined why the users would like my ideas.
	IOPT_06	*While evaluating my ideas:* I imagined why the users would dislike my ideas.
	IOPT_07	*While evaluating my ideas:* I imagined what aspects of my ideas that users would find enjoyable.
Imagine-Self Perspective-Taking (ISPT)	ISPT_04	*While evaluating my ideas:* To generate more design ideas, I imagined how I would feel if I were the user.
	ISPT_05	*While generating my design ideas:* I generated ideas by imagining that I were a user.
	ISPT_06	*While evaluating my ideas:* I imagined how I would use my ideas if I were the user.
	ISPT_07	*While evaluating my ideas:* I imagined what problems I would have when using my ideas if I were the user.
	ISPT_08	*While evaluating my ideas:* I evaluated my ideas by imagining that I were the user.
Affective Empathy (AE)	AE_02	*While generating my design ideas:* I felt happy when generating ideas that can be helpful to the users.
	AE_03	*While generating my design ideas:* I hoped that my ideas would be useful for the users.
	AE_04	*While evaluating my ideas:* I felt concerned when my ideas did not meet the needs of the users.
	AE_05	*While evaluating my ideas:* I felt happy when my ideas helped the users.

* Responses were on 7-point Likert-type scale where 1 = Not at all true of me and 7 = Very true of me.

items mapped to these constructs; the construct computations consist of the average of all items.

Finally, Phase 3 included a 19-item instrument [48] that asked students to reflect on their design experiences over the past semester (see Table 3). Students reflected on these experiences in three survey sections which are associated with three design phases: (1) needfinding, (2) concept generation, and (3) evaluation. Interspersed throughout these questions are three empathy types: (1) imagine-self perspective-taking (IOPT), (2) imagine-other perspective-taking (ISPT), and (3) affective empathy (AE).

Hess et al. [48] developed measurement models associated with (1) these three empathy types and (2) by empathy types paired with design phase. The authors achieved robust solutions in both configurations, but as the latter configuration included minimal internal consistency reliability (potentially due to few items on select constructs), only the former model configuration is used here. In this study, internal consistency reliability was checked among respondents and was found to exhibit good reliability in each instance (α_{IOPT} = 0.84; α_{ISPT} = 0.86; α_{AE} = 0.77).

3.4 Data Analysis Procedures

Data analysis procedures included computing descriptive statistics, including mean (M) and standard deviation (SD). Descriptive statistics are reported for the overall sample and by male/female respondent. Next, a series of two sample t-tests were used to compare responses between male and female respondents. In each t-test, the null hypothesis was that there would not be a significant difference across groups and the alternative hypothesis was that there would be a significant difference (two-tailed t-tests were used). Cohen's d [49] statistics were computed wherein $d > 0.80$ represents a large difference between responses, $d > 0.50$ represents a moderate difference, and $d > 0.20$ represents a small difference.

When testing multiple hypotheses simultaneously, the likelihood of committing a Type 1 Error increases (i.e., finding there exists a statistical difference when there is not one in reality). Thus, a Bonferroni correction was employed to adopt a more conservative threshold for significance, wherein the traditional threshold for significance ($\alpha = 0.05$) was divided by the number of hypotheses being tested [50]. Phase 1 and 2 each include two hypotheses and findings are marked as significant at $p < 0.025$ (Bonferonni), $p < 0.01$, and $p < 0.001$. Phase 3 included three hypotheses and findings are marked as significant at $p < 0.017$ (Bonferonni), $p < 0.01$ and $p < 0.001$.

Table 4. Descriptive statistics and comparisons tests between male and female biomedical engineering students' empathic tendencies at University 1

	Male			Female			Comparison Tests		
Construct	**n**	**M**	**SD**	**n**	**M**	**SD**	**t**	***p***	**d**
Perspective-Taking	55	6.31	1.41	56	6.64	1.49	1.22	0.224	0.23
Empathic Concern	55	6.11	1.56	56	7.02	1.54	3.11	0.002**	0.59

*$p < 0.025$; **$p < 0.01$; ***$p < 0.001$.

Table 5. Descriptive statistics and comparisons tests between male and female first-year engineering students' empathic tendencies at University 2

	Male			Female			Comparison Tests		
Construct	**n**	**M**	**SD**	**n**	**M**	**SD**	**t**	***p***	**d**
Perspective-Taking	312	6.25	1.02	104	6.52	1.04	2.25	0.025*	0.26
Empathic Concern	312	6.45	1.33	104	7.11	1.30	4.45	< 0.001***	0.50

*$p < 0.025$ (based on Bonferroni correction); **$p < 0.01$; ***$p < 0.001$.

Table 6. Descriptive statistics and comparisons tests between male and female first-year engineering students' use of empathy in design at University 2

		Male			Female			Comparison Tests		
Construct	**Items (α)**	**n**	**M**	**SD**	**n**	**M**	**SD**	**t**	***p***	**d**
Imagine-Other PT	IOPT_01, 02, 03, 04, 05, 06, & 07 (α = 0.84)	312	5.57	0.86	104	5.80	0.83	2.43	0.015*	0.27
Imagine-Self PT	ISPT_05, 06, 07, & 08 (α = 0.86)	312	5.64	0.92	104	5.89	0.89	2.45	0.015*	0.27
Affective Empathy	AE_02, 03, 04, & 05 (α = 0.77)	312	5.59	0.94	104	6.06	0.78	5.09	<0.001***	0.55

*$p < 0.017$ (based on Bonferroni correction); **$p < 0.01$; ***$p < 0.001$.

4. Results

4.1 Phase 1

Phase 1 addresses the research question, "How does empathy vary between male and female biomedical engineering students at a large urban university in the Midwest USA?" The findings indicate that female students reported significantly more empathic concern than their male peers (t = 3.11, $p < 0.01$) and these changes were moderate in effect (d = 0.59). While not significant (p = 0.224), female students also exhibited slightly higher responses in perspective-taking (d = 0.23). Table 4 summarizes these results.

4.2 Phase 2

Phase 2 addresses the research question, "How does empathy vary between male and female first-year engineering students at a large urban university in the Midwest USA?" This part compares first-year engineering students' responses at the end of a course in Fall 2019. As in Phase 1, female students exhibited significantly more empathic concern than their male peers (t = 4.45, $p < 0.001$) and, as in Phase 1, these changes were moderate (d = 0.50). Unlike Phase 1, female students reported significantly higher levels of perspective-taking (t = 2.25, $p <$ 0.025), but like Phase 1, these differences were small in effect (d = 0.26). Table 5 summarizes these results.

4.3 Phase 3

Phase 3 addresses the research question, "How does empathy's utilization in design vary between male and female first-year engineering students at a large public university in the Midwest USA?" The sample is the same as in Phase 2, but the constructs were distinct from Phases 1 and 2. Specifically, the survey tasked students to reflect on how they utilized empathy in their engineering design projects. As in Phases 1 and 2, a series of two sample t-tests were conducted to compare whether male and female students exhibited different levels of empathy, but here in the context of their engineering design projects in their courses.

We compared responses to Imagine-Other Perspective-Taking (IOPT), Imagine-Self Perspective-Taking (ISPT), and Affective Empathy (AE). Females reported greater levels of Affective Empathy in engineering design (t = 5.09, $p < 0.001$) and this difference was moderate in effect (d = 0.55). Female students also reported higher levels of IOPT (t = 2.43, $p < 0.017$, d = 0.27) and ISPT (t = 2.45, $p <$ 0.017, d = 0.27), but these differences were small in effect.

4.4 Summary of Results across Phases

The three study phases used different methodologies and examined different student populations. This summary briefly explores connections between the different parts of the study based on two empathy dimensions [41]: Affective and Cognitive Empathy.

Taken together, each phase suggested that female engineering students tend to be more affectively empathic, in general and in the context of engineering. Female students in biomedical engineering and first-year engineering both reported greater empathic concern tendencies than their male peers. First-year engineering female students also exhibited greater affective empathic during their first-year engineering design experiences than their male peers.

Findings regarding cognitive empathy were variable. In Phase 1, there was not a significant difference in perspective-taking between male and female biomedical engineering students, but in Phase 2, first-year engineering female students reported significantly greater perspective-taking tendencies. In Phase 3, female students reported greater use of cognitive empathy during their design project. Moreover, in each t-test, there was a small effect size with females reporting greater cognitive empathy than male peers.

5. Discussion

This study explored differences in male and female engineering students' empathic tendencies and usage of empathy in engineering design. Study findings suggested female engineering students were more likely than their male peers to (1) become empathically concerned towards others, in general and (2) to feel affective empathy for users during a first-year engineering design project. Females also reported greater perspective-taking tendencies and greater use of cognitive empathy during an engineering design project, but these differences exhibited small effect sizes. Thus, the findings support prior work which suggests that females in general [34, 35] and in engineering [36] exhibit greater empathy than male students, particularly when it comes to empathy's affective dimension.

This discussion extends these findings in three ways: (1) depicting empathy as a gendered phenomenon both beyond and within engineering; (2) identifying strategies for prompting empathy; (3) considering group membership and in-group/out-group bias; and (4) future work.

5.1 Empathy as a Gendered Phenomena

This study suggested there is a gendered nature of empathy in the engineering context. Chakrabarti and Baron-Cohen [35] found that "many studies converge on the conclusion that there is a female superiority in empathizing" (p. 408). There are numerous reasons undergirding these trends, but here I unpack two: steroid hormones and life experiences.

Carter et al. [51] suggested that "steroid hormones" are a primary reason for empathy differences between males and females, and they argued that neuropeptides (neuron-signaling protein-like molecules) and vasopressin (a hormone that maintains stability in particle concentrations in water surrounding brain cells) play an especially important role in empathy's manifestation. Recent research has focused on neuropeptides such as oxytocin and vasopressin and explored how these promote social cognition and interpersonal understanding. Dumais and Veenema [52] indicated that "sex-specific effects of intranasal VP [vasopressin] have been found in regards to social communication and cooperation." VP thus plays a role in "regulating social, emotional, and cognitive behaviors" and – as an example – can decrease males' perceptions of friendliness among while increasing females' perceptions of friendliness. Through events like this, neuropeptics can affect how individuals perceive others in distinct ways which can (in turn) inform the likelihood of whether one will empathize with those others.

Rochat [53] explored extant research on the development of empathy throughout one's life. They viewed cognitive empathic processes as largely "top-down" and informed largely by "self-imposed filters and contextual appraisal" (which are, themselves grounded in one's past experiences and beliefs). Conversely, bottom-up processes are more closely coupled with affective empathy. Such processes are an "*apparently* unmediated resonance mechanism" and they "imbue the cognitive [or top-down] components of empathy with an emotional engagement" (p. 720). When comparing male and female empathic approaches, bottom-up processes "tend to dominate and drive females' empathic responses" whereas males are more likely to empathize based on cognitive or top-down processes. These tendencies arise in early childhood and often follow individuals throughout their lifespans. As Rochat concluded, "From the outset of [childhood] development, bottom-up affective processes tend to dominate and drive females' empathic responses," whereas "top-down processes form a cardinal feature of males' responses" (p. 723). Thus, males and females may empathize in discrete ways as early as childhood, and their empathic proclivities may reinforce themselves during one's lifespan.

Chakrabarti and Baron-Cohen [35] suggested there were sixteen areas where females tend to exhibit more empathy than males. Example areas included "sharing and turn-taking," "responding empathically to the distress of other people," "sensitivity to facial expression," and "talk about emotions" (p. 409). Notably, these considerations align with the findings of this study, which indicated that female engineering students exhibited greater affective empathy in general (Phases 1 and 2) and in engineering design (Phase 3). While the 16 areas depicted by Chakrabarti and Baron-Cohen [35] often emphasized the affective domain of empathy, they also found that affective empathy can inform cognitive empathy. For example, these authors explored neural correlates of empathy and found that female students were better at engaging with using theory of mind (i.e., considering how another's mind functions) from as early as age three. Theory of mind is an empathy concept within the cognitive domain. In relation to the current study, theory of mind most closely resembles perspective-taking tendencies measured in Phases 1 and 2. Importantly, significant differences (i.e., female superiority) in perspective-taking were found in Phase 2 but not Phase 1. Future work ought to focus more concertedly on the interplay between affective and cognitive empathy, potentially by exploring the nature of how male and female engineering students engage in mode switching [1] or how male and female students respond to pedagogy designed to foster empathic formation.

5.2 Promoting Empathy in Engineering

This section offers three considerations for promoting empathy in engineering design.

First, instructors should examine how their learning environments promote or inhibit empathy, as such environmental factors inform empathic use [54]. As Walther et al. found [1], in the context of engineering, context and cultural features have a significant impact on how students developed and made use of empathy. In recognition of this, instructors should evaluate which contexts students view as part of the engineering learning experience and employ strategies to broaden student perspectives to see other contexts as offering potentially meaningful learning experiences. For example, if students see empathy for community members as instrumental to engineering design or their personal learning, they will be more likely to utilize empathy during their learning experiences.

Second, instructors should explicitly connect and discuss empathy (including its emotional aspects) to engineering processes. To this end, instructors may purposefully employ an empathic design framework [18, 23, 24, 28]. The use of such a framework should be made explicit and scaffolding may be needed to ensure that students (male and female) continually act in accordance with such processes. For example, instructors could prompt students to review Kouprie and Sleeswijk Visser's [26] empathic design model, provide students with resources to consider others' thoughts and feelings (such as an empathy map [55]), then ask students to immerse themselves in a user's world.

Third, instructors may prompt students to reflect on select empathy concepts or how empathy can inform their engineering processes. Such reflection activities should actively stretch students to reflective on affective empathy types (e.g., emotional congruence, emotion sharing, empathic distress, empathic concern) and, better yet, pursue opportunities for students to practice these empathy types and then reflect-on-action. For example, if seeking to promote empathic distress, an instructor might prime students to imagine ways that their design might fail, imagine themselves as users who would experience and must respond to the failure, and then identify the emotions that they would experience during this process. Aside from creating new prompts, instructors may use the instrumentation provided herein (i.e., Table 3) to help students evaluate their own levels of empathy and areas where they can better empathize.

5.3 Empathy and Group Membership

Group membership plays a key role in prejudice [56] and, in turn, empathy (or lack thereof). In-group/out-group bias refers to one's tendency to consider the needs and values of those whom one considers to be a friend or similar to themselves [10, 56]. In-groups may be defined by race, political affiliation, religion, or even gender. For males and females, biases such as this can detract from empathic activity (cognitive or affective). Yet, there are studies that have sought to work through challenges introduced by in-group/out-group biases.

One line of research has found that embodying an out-group racial member via an "avatar" [57, 58] can support empathy for those of other races. Farmer and Maister [58] built on this idea and found that one way to work around group membership bias is to "assign individuals to a 'new' social group [. . .] of which cut across existing social boundaries." They referenced Kurzban, Tooby, and Cosmides [59] who did just this and found:

> ". . . memory biases in favour of a racial in-group (White people) against a racial out-group (Black people) could be removed by four minutes of training that led to the association of some faces from each group as members of the same team as the participant with the effects previously associated with race now applying to the newly created in-group/out-group categories." [58]

In short, these studies suggest that enabling students to re-identify their group membership, or even recognize a new group membership, can help cultivate empathy among students. In the context of empathic design, where connection to users and immersion in their worlds is paramount, there is a specific need to consider the group distinction between the engineers themselves and the users/ community whom they aspire to help [12]. Should there be a misalignment between group membership, then there will likely be less empathy – thus, redefining group membership can play a key role in helping students better empathize with those beyond their initial inner circle by simply broadening that circle.

5.4 Limitations & Future Work

First, respondents in this study were asked to specify sex. Gender-specific data was not collected, which would have been a more appropriate and sensitive approach to data collection. As a result, this study does not discern nor report differences due to gender identity.

Second, the data reported in this study was entirely self-report data. The study's original motivation came from qualitative interviews that suggested greater use of empathy's affective elements among female engineers in a tissue harvesting lab [38]. Additional qualitative investigations should be conducted to more closely compare how empathy manifests across engineering students' genders, including but not limited to male and female students.

Third, these findings are from two universities, both from the Midwest United States, and among two student majors (biomedical engineering and first-year engineering). Thus, additional data collection and analyses need to be pursued in other engineering disciplines and universities.

6. Conclusion

In the context of engineering, few studies have directly compared empathy between males and females. This study sought to address this gap by exploring variation in empathic tendencies and usage in engineering design between male and female engineering students. Phases 1 and 2 revealed that female students report higher affective empathy, and Phase 3 suggested that this translated to engineering design. While the changes were small in effect size, Phase 2 suggested greater perspective-taking tendencies among female students and Phase 3 suggested that female students were more likely to employ perspective-taking in design. Taken together, these findings suggest that female engineering students are, overall, superior empathizers than their male counterparts, especially when we focus on affective empathy. Thus, engineering instructors, particularly those wishing to promote empathy in their curricula, ought to find ways to capitalize on the empathic strengths of female students.

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