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Empathy in Engineering Design Teams: Comparing Hybrid and Online Learners*

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Empathy is essential to engineering education, including in the domains of teamwork and design. Empathy enables engineers to consider the perspectives of their peers and can motivate teammates to act upon such understandings in supportive ways. Yet, we lack knowledge on how empathy manifests within teamwork settings or how best to promote its use in learning contexts. We aim to fill this knowledge gap by addressing two research questions: (1) "To what extent are there differences in empathy with/for team members in hybrid versus online learning modalities?" and (2) "To what extent are their correlations between empathy constructs in hybrid and online learning modalities?" We administered a survey to First-Year engineering students at a large Midwestern University in Fall 2021 which included seven constructs: Perspective-Taking, Empathic Concern, Perspective-Taking with/for teammates, Empathic Concern with/for teammates, Cognitive Collective Empathy, Affective Collective Empathy, and Behavioral Collective Empathy. First, we used non-parametric tests to compare how constructs manifested in two learning modalities (online-only and hybrid). Next, we computed Pearson's correlations to identify relationships between constructs. Our findings revealed no significant differences in how empathy manifested with/for teammates across learning modalities. There were strong correlations between the empathy constructs for both groups, but the nature of these correlations varied, with slightly larger correlations between empathic states and traits among Hybrid learners when compared to Online-only students. In our discussion, we identify lessons for promoting and assessing empathy in online and hybrid instructional modalities. This work will support engineering instructors and researchers in the assessment and promotion of empathy in engineering curriculums.

Keywords: empathy; teams; hybrid; online; instruction

1. Introduction

Effective teamwork skills enable engineering students to address complex socio-technical engineering problems [1], be more creative [2], and act more inclusively [3]. To these ends, engineering programs have designed courses to promote empathic formation during teamwork-based projects [4, 5]. Specifically, during teamwork interactions, students must practice empathy to understand and leverage team members' diverse perspectives [6] and to realize the team's collective creative potential [7].

Recently, there has been much attention on virtual modalities of instruction due to COVID-19 [8, 9] and aspirations to shift engineering education to become more accessible to online learners [10, 11]. Whether online or in-person, collaborative experiences are important for becoming a professional engineer [12]. Yet, while empathy is one critical element of teamwork experiences in engineering, we know relatively little regarding how empathy forms in teamwork contexts in engineering [13, 14], nor how empathic use or formation varies between online and hybrid learning contexts [15–17]. This paper seeks to address this gap.

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Building on these considerations, we begin this study with the premise that empathy is critical for engineering design [18, 19] and can play an especially important role in successful teaming experiences [20, 21]. However, given challenges associated with team communication in virtual settings [4, 22], we posit that empathy with/for teammates will be more prominent in hybrid versus virtual learning modalities, as hybrid modalities afford in-person interactions. We address this hypothesis by comparing how empathy manifests with/for team members across two learning contexts. The psychometrics we use in this study provide tools for assessing empathy that account for how empathy manifests as a disposition (i.e., as a trait) versus how empathy manifests with/for team members (i.e., as a state). Taken together, study findings and these tools will generate findings and strategies for others to better understand and promote their students' use of empathy in engineering design.

2. Background and Motivation

2.1 What is Empathy?

Empathy is a multidimensional concept [23, 24], which can be understood as a discrete but related set of skills, orientations, and ways of being [25].

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Batson [23] identified eight empathy types, which Hess & Fila [16] paraphrased as: (1) ''empathic accuracy,'' (2) ''motor mimicry,'' (3) ''emotional contagion,'' (4) ''projection,'' (5) ''perspective-taking (imagine-other),'' (6) ''perspective taking (imagine-self),'' (7) ''empathic distress,'' and (8) ''empathic concern.'' These conceptions vary in their emphasis on affective experiences versus cognitive processes and self-versus-other orientation [16]. There also exist at least eight extant tensions in definitions of empathy [26], including (1) whether empathy is primarily cognitive or affective, (2) how empathy relates/differs from other phenomena (especially sympathy), and (3) the extent and necessity of self/other psychological merging. As a result of these tensions, many scholars generally study one or multiple select empathy ''concepts'' in their research [23]. It is thus critical to attend to how authors define empathy whilst studying it, as individual empathy concepts are – in theory – discretely measurable [24, 27].

Clark et al. [28] argued that organizational research studies measure three empathy ''dimensions'': affective, cognitive, and behavioral. This tripartite operationalization has been utilized to measure empathy in workplace settings [28] as well as in engineering teamwork settings [13]. According to Clark et al. [28], (1) affective empathy includes ''feeling the same affective state as another person,'' (2) cognitive empathy involves developing an understanding of the internal feelings or thoughts of another person, and (3) behavioral empathy involves acting upon affective and/or cognitive empathy (p. 167). Another extant tension in ways of defining empathy finds scholars arguing whether behavior is a dimension of empathy or an outcome resulting from cognitive and/or affective empathy [26].

Another way to define empathy involves differentiating between one's tendency to empathize versus one's actual and real-time use of empathy. To this end, Clark et al. [28] differentiated between trait and state empathy, wherein (1) trait empathy refers to one's general empathic tendencies or how one tends to employ empathy and (2) state empathy refers to how one empathizes in specific situations and at specifics moments in time. Clark et al. [28] further argued that how empathy manifests in one context may be dissimilar when compared to another. For example, how one empathizes in engineering teams may differ from how one empathizes in everyday life encounters. Similar sentiments have been explored in the context of engineering design [29, 30].

Collective empathy offers another way to define empathy [13] and ''emphasizes the interrelationships between individuals, such as the members of a team, including the extent to which members exhibit emotional rapport and appreciate others' thoughts and perspectives'' [14]. This concept emphasizes emotion sharing across the group (affective), the generation of ideas holistically and as a group (cognitive), or responding to team members' thoughts and feelings (behavior) [13]. Akgün and colleagues' [13] collective empathy survey items prompt students to reflect on state-specific experiences over time, thus measuring how the team *tended* to share cognitions, affects, or behaviors – thus, it seems to straddle the state/trait distinction offered by Clark et al. [28].

2.2 How Has Empathy Been Studied in Engineering Education?

A focus on empathy in engineering education is relatively novel when compared to other fields [31]. Walther et al. [25] juxtaposed engineering education understandings of empathy with those from social work. They generated three characterizations of empathy for situating empathy in engineering, including ''as a learnable skill'' (p. 134), a ''practice orientation'' (p. 135), or a ''professional way of being'' (p. 137) [25]. Empathy as a skill draws attention to the purposeful and learnable use of empathy, empathy as an orientation considers facets that enable one to enact the skills, and empathy as a way of being focuses on the manifestation of professional empathic behaviors (e.g., ''service to society''). This framework comprises what others may call antecedents and associated skills/orientations [32, 33] that are critical for cognitive and affective dimensions to manifest as behavioral empathy [28]. Like other research studies on empathy in engineering, a practical focus on what empathy looks like in practice is evident in this framework [33], [34].

Prominent areas of research on empathy in engineering education include engineering design [16, 34–41], communication [42–44], and teamwork skills [1–3]. Many studies are quantitative in nature and, like organizational research studies [28], have often used Davis's [24] IRI or Interpersonal Reactivity Index (e.g., [45–47]). Such quantitative studies have employed the four IRI constructs which measure individuals' empathic traits: perspective-taking, empathic concern, fantasy, and personal distress [35]. Other scholars have studied the relationships between empathic tendencies and select orientations or behaviors. For example, Lin et al. [48] investigated the extent to which civic-mindedness explained first-year engineering students' empathic tendencies or traits (perspective-taking and empathic concern). They found that these empathic tendencies were each strong predictors of civic-mindedness, and each were strong predic-

tors of interpersonal communication. Hess et al. [38] studied how empathy informed innovation and found that empathy constructs were strong predictors of innovative behavioral tendencies (e.g., perspective-taking positively predicted observation, questioning, and experimenting and empathic concern positively predicted questioning, observation, and idea networking). Apfelbaum et al. [6] triangulated student responses from the IRI with empathic behaviors that they observed in student assignments and found that the development of empathic traits did not always translate into empathic practices in students' design projects. As the authors wrote, ''it is not trait empathy that leads to empathic design, but rather applied empathy in the design process'' (p. 1). Separately, Alzayed et al. [35] collected IRI data, qualitatively explored students' reflections of their empathy use in engineering design teams, and then triangulated these data. They computed team empathy as the average of the individual traits (perspective-taking, empathic concern, and fantasy) and found that this positively informed creativity and design outcomes. Thus, these studies highlight myriad roles empathy might play in engineering design based on utilizing a common instrument (i.e., the IRI).

While the IRI is a common instrument utilized to assess empathy in engineering education, it measures individual tendencies. However, a focus on the *collective* in engineering is emergent (e.g., collective intelligence, [49]; collective action, [50], and collective emotions or ''team emotional intelligence,'' see [51]), including collective empathy in engineering education [14, 46, 47]. Akgün et al. [13] measured three collective empathy dimensions (cognitive, affective, and behavioral) in the context of software development teams and explored their relationship with multiple teamwork constructs [13]. They found that collective empathy had a significant positive effect on teamwork performance and, conversely, that aspects of the team informed the development of collective empathy. Hess et al. [14] collected and analyzed post-course interview discourses from biomedical engineering design student teams and found that students generally expressed a collective team perspective rather than empathy with/for select team members. These works focused on in-person teaming contexts, whereas the current study applies the operationalization of collective empathy to virtual instructional modalities.

2.3 How do Students develop Empathy with/for Teammates in Online Learning Modalites?

The ''No Significant Difference phenomenon'' argues that learning outcomes in virtual and in-person instructional modalities tend to be similar [52]. While this finding may hold for one's learning of content, it may not transfer to the development of empathy with/for team members due to miscellaneous challenges presented therein.

Potential challenges for empathic formation associated with virtual team experiences include relationship-building, ambiguity resultant from remote communication, geographical and temporal distance, diversity of team members, and the need for reliable and user-friendly technology [53, 54]. Gamero et al. [51] identified challenges with generating emotional understanding among team members in virtual settings, with one prominent barrier being computer-mediated communication. Separately, Jaiswal et al. [4] identified ''challenges due to virtual team communication'' in engineering design teams, including a ''lack of equal participation/contribution'' and a ''lack of social sensitivity'' (p. 8). Finally, Nguyen and Canny [17] explored how ''video framing'' affected students' empathic development and found that when students interacted virtually and when an individual's camera showed less of their body, the observer was less likely to exhibit behavioral empathy when later interacting in-person (they used the ''pen drop'' experiment to measure behavioral responsiveness). Thus, myriad challenges that are unique to online learning can negatively influence whether virtual team members will empathize with their other virtual team members.

While the above studies noted challenges in team members' empathic formation in online settings, they also may offer strategies to promote empathy with/for team members. Building on Nguyen and Canney [17], one suggestion is to have virtual teams use video features, but also to show more of their upper body (rather than their face alone). Jaiswal et al. [4] generated three strategies from their student data for improving team communication, including ''equal contribution,'' ''social sensitivity,'' and ''empathy'' (p. 8). Thus, empathy here serves as a way for students to become more understanding and supportive of their peers, but we conjecture from Hess et al. [14] that there will be a feedback loop between effective communication and empathic use. Dube and Robey [55] suggested social interaction is critical to boosting team performance; while perhaps seemingly paradoxical, the idea is that informal interactions can promote empathy and bolster team performance. A similar theory was expressed by Akgün et al. [13] for promoting collective empathy in teams, regardless of modality.

As the above strategies suggest, virtual instruction offers unique challenges when compared to face-to-face or hybrid learning modalities, but these strategies can be offset with intentional pedagogical choices to promote empathy between team

members. Nonetheless, as the time commitment of virtual instruction can already be significantly higher than face-to-face modalities [56], these extra instructional strategies add to an already time-intensive endeavor. In addition, some students may thrive in online learning settings whereas others may struggle in online contexts based on the novelty of online learning, learning styles, time management skills, internal motivation, or other cognitive capacities [56]. Thus, while there can be successes in online instruction, including (potentially) for promoting empathy with/for team members, due to the unique challenges of virtual instruction, we hypothesize that students who participate in virtual learning modalities will exhibit less empathy with/for teammates than peers who are in-person.

3. Methods

3.1 Author Positionality

We share our positionality, including our identities and research journeys [57], to contextualize this study. At the time of data collection, analysis, and narration, our two-member team included a PhD candidate in Engineering Education (Carrillo-Fernandez) and an assistant professor in Engineering Education (Hess). Both authors were males and had prior experiences in the course around which we collected data in this study. At the time of data collection (Fall 2021), one author was an instructor in this course (Hess) and one author was a graduate teaching assistant (Carrillo-Fernandez). Both authors had prior experiences in the engineering industry, and each brought disciplinary backgrounds from different domains of engineering. One author was from a European country and Spanish was his first language and the other author was from the United States and English was his first language. Based on our prior workforce and academic experiences, we felt that empathy was critical to teamwork. Throughout the design and implementation of this study, we discussed the use of complex terms and negotiated their definitions. For example, we each were developing an emergent understanding of collective empathy. Finally, we each sought to situate study findings in engineering education literature and to provide actional strategies for instructors to introduce empathy or promote its formation in engineering curricular contexts.

3.2 Course Context

The course from which we collected data for this study was a required first-year engineering course at a Large Midwestern University. Course sections included up to 120 students, four peer teachers, a graduate teaching assistant, and a lead instructor. The course included three main projects over the course of the four-month academic semester, with the final project being a team-based design project. Project topics varied by instructor/section and included (1) designing toys for children, (2) designing for campus mobility, and (3) designing a waste sorting system for compositing. The course had students complete online activities before coming to each class session (be they virtual or in-person). During two-hour class sessions, instructors reinforced important content and then students worked individually or in teams. The four peer teachers and the graduate teaching assistant provided formative guidance and support to learners. During the design project, students worked in teams of four for at least half of each class session. This structure afforded us the opportunity to interact with students in our sections and observe their learning and interactions. One important note to share regarding this study is that during the Fall 2021 semester, all students wore masks while in-class. Many students missed classes due to illness (including but not limited to COVID-19). We observed that the overall course experience was stressful for many students and instructors and mental health was a prominent campus issue and concern.

3.3 Data Collection

3.3.1 Participant Overview

We collected survey data in Fall 2021 from students enrolled in a first-year engineering course that included a design project at a large, public university in the Midwest, USA. We administered the survey near the end of the semester, after students had completed most of the course. We sent the survey to ten sections, each comprised of 120 students, and 522 students completed the survey. After cleaning data, we included 508 responses in analysis. Of those 508 participants, 96 enrolled in the one virtual section. There was general alignment in demographics across sections, although the Hybrid modality included a greater relative percentage of male participants (70.1%) when compared to the online modality (54.6%). Table 1 summarizes participants demographics by instructional modality.

3.3.2 Survey Overview

We collected seven survey constructs comprised of between 3 and 7 items, or 41 items total. We grouped constructs into three categories: (1) empathic tendencies, (2) empathy with/for teammates, and (3) collective empathy. For each item, participants selected a response on a Likert scale from 1 to 6, where 1 represented strong disagreement and 6 represented strong agreement. We do

Table 1. Participant Overview (n = 508)

	Hybrid Modality		Online-Only Modality	
	n	**Relative %**	**n**	**Relative %**
Participants	412	100	96	100%
Gender	–	–	–	–
Female	115	27.8	39	40.6
Male	289	70.1	53	54.6
Trans masculine	3	0.7	–	–
Non-binary	–	–	2	2.1
Prefer not to disclose	4	1	1	1
Not responded	1	0.2	1	1
Race/Ethnicity	–	–	–	–
American Indian or Alaska Native	1	0.2	–	–
Asian	81	19.6	21	21.6
Black or African American	7	1.7	2	2.1
Hispanic or Latino	14	3.4	3	3.1
White or Caucasian	258	62.6	57	59.4
Multiracial	36	8.7	8	8.2
Other	5	1.2	–	–
Declined to Specify	10	2.4	4	4.1
Not declared	–	–	1	1

not share Akgün et al.'s [13] survey items due to copyright.

First, we measured Perspective-Taking (PT) and Empathic Concern (EC) using the Interpersonal Reactivity Index or IRI [24]. The PT construct included seven items that assess a respondent's tendency to view the world from another's perspective [24]. The EC construct included seven items and assessed a respondent's tendency to become concerned for others, particularly when others experience negative situations (e.g., when others are "having problems" or are "being taken advantage of"). For shorthand, throughout the remainder of this manuscript, we use EC_{trait} and PT_{trait} when referring to these original IRI constructs.

Second, we modified PT and EC constructs from the IRI to measure empathy with/for team members. These modified constructs prompted respondents to reflect upon their team experiences, thus contextualizing their thinking process with/for team members [71]. We sought to minimize modifications; thus, items in modified constructs included most of the language from the original IRI constructs. For example, an item from PT_{trait} stated, "I try to look at everybody's side of a disagreement before I make a decision," whereas the modified PT stated, "I try to look at **my teammates'** side of a disagreement before I make **any** decisions" (modifications are in bold). Similarly, an item from EC_{trait} stated, "When I see someone being taken advantage of, I feel kind of protective towards them," whereas the modified EC stated, "When I see **my teammates** being taken advantage of, I feel kind of protective towards them." Throughout the rest of this manuscript, we use EC_{team} and PT_{team} to represent these modified IRI constructs.

Third, we employed three constructs from Akgün et al. [13]: Affective Collective Empathy (ACE), Behavioral Collective Empathy (BCE), and Cognitive Collective Empathy (CCE). ACE evaluates the shared feelings within one's design team [13]. An example ACE item is: "Our team members tend to get emotionally involved with others' feelings within our team." The CCE construct measures the team's formation of a shared team perspective or the ability of the team to generate such a shared perspective [13]. An example item from CCE is: "Our team members are able to see things from each other's points of view." The BCE construct measures "the outward display of empathy or affective responsiveness" [13, p. 248] towards team members. An example BCE item is: "Our team members react in response to the feelings of others within our team." Thus, these three constructs ostensibly provide measures of three collective empathy dimensions which account for empathy by and for everyone within the team, whereas PT_{team} and EC_{team} (i.e., the modified IRI constructs) measure one's own use of two empathy concepts.

3.4 Data Analysis

3.4.1 Cleaning Data

We initially received 522 survey responses but excluded 14 responses from our analysis. First, we excluded 11 responses where students inappropriately responded to dummy items (e.g., respondents

may have selected "4" to a question that stated, "Please select 3 to this response"). Of the remaining 511 responses, we excluded one due to the participant's repetitive pattern response (i.e., the participant selected "Strongly agree" for all 41 items in the survey; as some items were negatively worded, they thus responded to competing sentiments in erroneous ways). Of the remaining 510 responses, we identified two outliers which exhibited construct responses higher than three standard deviations from the mean [58]. The final number of the sample was 508, including 412 in hybrid and 96 in online instruction.

3.4.2 Checking Internal Consistency Reliability

Next, we computed the internal consistency of all variables by checking Cronbach's alpha. Nearly all constructs were reliable (i.e., $\alpha > 0.70$) but two constructs were minimally reliable [59]: Empathic Concern from the IRI ($\alpha = 0.67$) and Affective Collective Empathy ($\alpha = 0.65$). As these two constructs were near the sought 0.70 threshold and given the historical usage of the IRI in engineering education literature, we chose to retain constructs as originally developed rather than removing items to improve reliability.

3.4.3 Checking Normality

We next checked assumptions for normality by checking construct histograms and computing the Shapiro-Wilk's coefficient for each construct. We used this test to identify if the data were approximately non-normal. When we reviewed these results for each group, we found that responses to Empathic Concern from the IRI and Cognitive Collective Empathy were approximately non-normal for each. We also found that Perspective-Taking from the IRI was non-normal for the online group and that Empathic Concern with/for Teammates and Behavioral Collective Empathy were non-normal for the Hybrid Group.

3.4.4 Comparing Empathy Constructs by Instructional Modality

We computed construct scores by taking the average of items on select constructs. Next, we analyzed the median, mean, and standard deviation of constructs based on instructional modality. We then tested differences between hybrid and online instruction for each construct. Due to the non-normal nature of responses to many constructs, we used the two-sample Mann-Whitney U test [60]. For these tests, the null hypothesis was that there would not be a significant difference across groups on state-specific empathy constructs (i.e., EC_{trait}, PT_{trait}, ACE, CCE, BCE) and the alternative hypothesis was that there would be a significant difference across groups – we thus utilized a two-tailed t-test.

To perform the Mann-Whitney U Test, construct responses for both groups are considered together, sorted from lowest to highest, and each individual response is assigned a rank based on their order. These "ranks" are then summed for each group (T) and the "mean rank" is this value divided by the respective sample size. U for each group (U_{group}) is then computed by multiplying the sample size for each group ($n_1 = 412$ and $n_2 = 96$), subtracting the rank sums for the respective group (T), and then adding the following: [n + (n + 1)]/2. Next, we computed z as follows:

$$z = \frac{U - (0.5 * n_1 * n_2)}{\sqrt{\frac{n_1 * n_2 * (n_1 + n_2 + 1)}{12}}}$$

3.4.5 Computing Pearsons Correlation Coefficient

Correlation analysis brings several assumptions [61] including continuous data, linear relationships between variables, no outliers, and a normal (or near normal) distribution. In our study, (1) each construct was continuous; (2) the constructs had approximately linear relationship (based on a review of scatterplots), (3) we removed outliers (see data cleaning section above), but (4) we found that construct responses were approximately non-normal. Despite this last limitation, we computed Person's correlation coefficient to identify relationships among constructs. We computed these coefficients for hybrid and online instructional modalities separately. We observe and discuss differences between correlations in the discussion.

4. Results

4.1 Descriptive Statistics

In Table 2, we present the median (Md), mean (M), and standard deviation (SD) of each construct by instructional modality. For both groups of learners, students exhibited the highest responses to EC_{trait} ($Md = 4.57$ for hybrid students; $Md = 4.78$ for online students) when compared to other constructs. Conversely, PT_{team} was higher than EC_{team} for both groups. Thus, while EC_{trait} was greater than PT_{trait} for both groups, students reported exhibiting perspective-taking within the team setting to a greater degree than empathic concern. As we review the collective empathy constructs, CCE is the highest response among the hybrid and online groups ($Md = 4.17$ for hybrid students; $Md = 4.33$ for online students), but Online learners reported BCE to the same extent as CCE (i.e., $Md = 4.33$). For both groups, CCE was slightly lower than PT_{team} and ACE was less than EC_{team}.

Table 2. Descriptive Statistics (n_{hybrid} = 412 and n_{online} = 96)

Instrument	Variable	Hybrid (n = 412)			Online (n = 96)		
		Md	***M***	***SD***	***Md***	***M***	***SD***
Original IRI [24]	EC_{trait}	4.57	4.59	0.61	4.78	4.73	0.63
	PT_{trait}	4.29	4.28	0.65	4.43	4.30	0.76
Modified IRI	EC_{team}	4.29	4.24	0.71	4.29	4.30	0.79
	PT_{team}	4.43	4.42	0.66	4.36	4.46	0.69
Collective Empathy [13]	CCE	4.17	4.16	0.79	4.33	4.16	0.88
	ACE	3.75	3.58	0.77	3.75	3.58	0.78
	BCE	4.00	3.95	0.85	4.33	4.14	0.82

Note: Scores were measured on a Likert Scale of 1 (Strongly Disagree) to 6 (Strongly Agree). SD = standard deviation.

Table 3. Mann Whitney U Test Results (n_{hybrid} = 412 and n_{online} = 96)

	Hybrid	**Online**	**z**	***p***	**r (effect size)**
EC_{trait}	248.1	281.9	–2.037	0.042	0.090
PT_{trait}	253.2	260.2	–0.423	0.672	0.019

Table 4. Mann Whitney U Test Results (n_{hybrid} = 412 and n_{online} = 96)

	Hybrid	**Online**	**z**	***p***	**r (effect size)**
EC_{team}	252.07	264.92	–0.774	0.439	0.034
PT_{team}	254.08	256.29	–0.133	0.894	0.006
CCE	252.97	261.05	–0.487	0.626	0.022
ACE	254.95	252.59	–0.142	0.887	0.006
BCE	248.40	280.70	–1.959	0.050	0.087

4.1.1 Comparing Empathic Traits across Groups

We performed two Mann-Whitney U tests to evaluate whether empathic traits differed by students who participated in online or hybrid learning modalities. This test enabled us to establish the extent to which empathic traits may have influenced the manifestation of empathic traits within team settings. The results indicated that there was a significant difference between EC_{trait} between hybrid and online instructional modalities ($z = –2.037$, $p = 0.042$) wherein online learners exhibited superiority in EC_{trait} when compared to hybrid leaners. There was no significant difference between PT_{trait} ($z = –0.423$, $p = 0.672$). Table 3 summarizes these results.

Based on this analysis, regardless of instructional modality, and given the antecedent nature of dispositional empathy [65], we would expect higher levels of EC among online learners when compared to hybrid learners. However, given the challenges of online instruction (see Background and Motivation), and given the potential dual impact of individual antecedents (such as individual tendencies to become empathically concerned) and situational antecedents (such as the challenges of empathizing in online settings), we might rather revise our original hypothesis in light of this finding. Namely, due to the greater empathic concern tendencies reported among students who participated in the virtual modality, we would hypothesize that there would be no significant differences in empathic concern with/for team members (EC_{team}) based on instructional modality. As there was no significant difference between PT_{trait} by group, we would still expect PT_{team} to be greater among Hybrid versus Online learners.

4.1.2 Comparing Empathic States across Groups

Five Mann-Whitney U tests were performed to evaluate whether empathy with/for teammates and collective empathy differed by students who participated in online or hybrid learning modalities. For each test, the alternative hypothesis was that there would not be a significant difference across groups – we thus utilized a two-tailed t-test. The results indicated that (1) there was no significant difference between EC_{team} ($z = –0.774$, $p = 0.439$) but there was a small effect size indicating slight superiority among Online students; (2) there was no significant difference between PT_{team} across groups ($z = –0.133$, $p = 0.894$); (3) there was no significant difference between CCE ($z = –0487$, $p = 0.626$) but we found a small effect size indicating superiority among Online learners; (4) there was no significant difference between ACE by group ($z = –0.142$, $p = 0.887$); and (5) there was no significant difference between BCE across groups ($z = –1.959$, $p = 0.05$) but this exhibited a near-moderate effect size with superiority among Online learners.

Table 5. Pearson Correlation Matrix for Hybrid Students (n_{hybrid} = 412)

	EC_{trait}	**PT_{trait}**	**EC_{team}**	**PT_{team}**	**CCE**	ACE	BCE
EC_{trait}	1	0.449***	0.602***	0.443***	0.228***	0.185***	0.145***
PT_{trait}		1	0.412***	0.691***	0.296***	0.225***	0.283***
EC_{team}			1	0.616***	0.519***	0.460***	0.470***
PT_{team}				1	0.534***	0.360***	0.453***
CCE					1	0.573***	0.746***
ACE						1	0.563***
BCE							1

***p < 0.001; **p < 0.01; *p < 0.05.

Table 6. Pearson Correlation Matrix for Online Students (n_{online} = 96)

	EC_{trait}	**PT_{trait}**	**EC_{team}**	**PT_{team}**	**CCE**	**ACE**	**BCE**
EC_{trait}	1	0.515***	0.547***	0.414***	0.315**	0.197	0.203*
PT_{trait}		1	0.389***	0.650***	0.332**	0.213*	0.259*
EC_{team}			1	0.563***	0.530***	0.370***	0.423***
PT_{team}				1	0.479***	0.252*	0.369***
CCE					1	0.592***	0.779***
ACE						1	0.607***
BCE							1

***p < 0.001; **p < 0.01; *p < 0.05.

These data suggest that there was no significant difference in empathy with/for team members or throughout the team context during the course design project. However, several constructs exhibited small effect sizes revealing empathic superiority among students in Online learning settings. These findings were most surprising for Behavioral Collective Empathy, which exhibited a moderate effect size in favor of the Online learners. In retrospect, and after reviewing the items associated with this construct, we posit that there may have been greater interpersonal responsiveness and reactivity in online settings due to myriad factors, such as the ability to communicate in safe environments (e.g., one's home) and the ability to observe peer faces in online settings (Hybrid students wore masks during class sessions). We expand on this line of reasoning in the discussion.

4.1.3 Correlation Analysis

We next computed Pearson's *r* which measures relationships between constructs. Tables 5 and 6 show these results for Hybrid and Online students, respectively. For students who participated in the Hybrid modality, every correlation was significant at $p < 0.001$ (two-tailed). The strongest relationships (and strong effect sizes) were between CCE and BCE ($r = 0.746$), PT_{trait} and PT_{team} ($r = 0.691$), PT_{team} and EC_{team} ($r = 0.616$), and EC_{trait} and EC_{team} ($r = 0.602$).

For students who participated in the online modality, most correlations were significant at $p < 0.001$, several were significant at $p < 0.01$, one was significant at $p < 0.05$ (PT_{team} and ACE), and one was not significant (EC_{trait} and ACE). Like Hybrid learners, the strongest relationships were again between CCE and BCE ($r = 0.779$). Several other variables exhibited strong effect sizes (i.e., $r > 0.50$), including PT_{team} and PT_{trait} ($r = 0.650$), BCE and ACE ($r = 0.607$), and ACE and CCE ($r = 0.592$).

The large effect sizes exhibited across both groups supports the alignment between empathy constructs. When looking at correlations across modalities, EC_{trait} and EC_{team} exhibited slightly more positive correlations between Hybrid ($r = 0.602$) than Online ($r = 0.547$) learners. Similarly, PT_{trait} and PT_{team} exhibited a slightly more positive correlation among Hybrid ($r = 0.691$) than Online ($r = 0.650$) learners. Thus, despite online learners EC_{trait} superiority, in-class students seemed slightly better positioned to translate their empathic concern traits into the team context. The lesser significance of correlations between the two empathic trait constructs and the three collective empathy constructs among online learners when compared to hybrid students seems to add to this pattern. We extend this line of thinking in the discussion.

5. Discussion

This study compared how empathy manifested in Hybrid and Online learning contexts in a First-Year Engineering design project. We applied two prominently used empathy constructs, Empathic Concern and Perspective-Taking from the Interpersonal Reactivity Index or IRI [24]. We framed these

constructs as measures of empathic ''traits'' [28], thus calling attention to their dispositional nature. We next modified items on these constructs to measure empathy with/for teammates and we framed these as measures of empathic ''states'' [28], thus calling attention to their contextual nature. Finally, we used three collective empathy constructs from Akgün et al. [13]: Affective, Behavioral, and Cognitive Collective Empathy – we framed these three constructs as ''state measures'' that measure empathy as it manifested by and for all members within the team. We found no significant differences across constructs based on learning modalities. However, we discerned a few patterns when observing correlations between constructs by group.

In this discussion, we contextualize our results by identifying (1) factors that potentially influence empathy's manifestation with/for team members in engineering curriculums, including but not limited to engineering design contexts, (2) approaches for assessing empathy, and (3) limitations and future work.

5.1 Factors that Influence Empathy's Manifestation

Our primary goal was to explore differences in how empathy manifests in teamwork contexts by comparing responses to empathy constructs amongst learners in Hybrid versus Online Learning contexts. We hypothesized that Hybrid learners would exhibit greater empathy with/for teammates given myriad challenges in Online-only team contexts [53, 54, 62–64]. Our findings revealed that there was no significant difference in how empathy manifested with/for teammates across contexts. We were surprised by these findings, and thus considered potential reasons for the lack of significant differences. Through this reflection, we identified four factors that may have influenced empathy's manifestation in hybrid and online learning contexts. We argue that these considerations can inform the teaching of empathy in other instructional contexts, be it in-person, hybrid, or online.

First, we presumed that one's trait empathy may serve as an antecedent to empathy's manifestation in team settings [65]. To this end, we observed that Online learners reported greater levels of trait empathy, but *not* significantly greater empathy with/for teammates. As empathic traits can serve as an antecedent to empathy's manifestation [65], we noted the greater trait empathy among Online-only learners as a potential reason for the lack of significant differences in empathy with/for teammates across contexts. Second, the trait/state constructs (i.e., EC_{trait}/EC_{team} and PT_{trait}/PT_{team}) exhibited positive correlations with large effect sizes for both instructional modalities. However, among Hybrid respondents, these correlations tended to be slightly larger. Thus, the translation of one's empathic traits to empathy with/for team members seems to have been greater in the Hybrid context, albeit, to a limited degree.

Second, mask-wearing may have inhibited empathy's manifestation for in-class team members due to the lack of facial observations, mimicry, and associated phenomenon. Our initial hypothesis was that students in-class would exhibit higher levels of empathy than online-only students, but in retrospect, the lack of facial observations may play a key role in empathy's manifestation, particularly its affective dimensions [66]. To this point, Hayirli et al. [67] found that masking while engaging in urgent care disturbed relationships among team members by making social interactions more difficult, communication cumbersome, and facial recognition difficult. As the authors shared succinctly, ''You are much less visible [and, as a result] much less human'' [67, p. 3]. As instructors of the course, we observed similar social interaction challenges during classroom sessions. Importantly, while students may have interacted with peers outside of class, the class was structured in such a way so that (ideally) students could achieve most of their assignments during classroom sessions. Thus, in theory, interactions outside of the classroom were not necessary.

Third, the state of the US (i.e., the pandemic, racial injustices, political unrest) at the time of data collection may have enhanced students empathic proclivities regardless of learning modality. The pandemic impacted students' academic and social lives, including their depression, stress, anxiety, and boredom [9]. Balta-Salvador et al. [9] observed engineering undergraduate students from different cohorts and found that the pandemic prompted students to connect with other students and teachers, including relating to others' emotions. As a result of the pandemic, many students and instructors began experimenting with and experiencing online learning for the first time, and many individuals thus potentially became comfortable working in such an environment [9]. We posit that, taken together, students may have become more comfortable engaging in online social interactions when compared to their teaming experiences by Fall 2021.

Finally, we questioned whether the instructor of the Online course positively promoted empathy, perhaps in ways above and beyond instructors in Hybrid sections. This instructor reported teaching this course online during the Fall 2020, Spring 2021, Summer 2021, and finally, Fall 2021 semester. The instructor was thus experienced in online instruction, and they even reported studying online teaching methods and students' online engagement,

including prompting students to practice perspective-taking by reflecting on how people (including, ostensibly, team members) do things differently and bring distinct life experiences. While they did not require students to use cameras during team interactions, it was strongly suggested to form connections between team members, to improve teamwork processes, to develop friendships, to build connections, and to promote belongingness. The instructor also posed team-based questions that were unique to their course section (e.g., ''If your team would go to a concert, which one would it be?''). Our sense is that such activities prompted empathy with/for team members in this course in positive ways that were unique when compared to other course sections.

5.2 *Considerations for Assessing Empathy*

Given empathy's multidimensional nature [23, 24], we theorized that the empathy constructs each represented empathy in different ways and each played distinct roles in teamwork and engineering design. Moreover, our analysis supports the distinction between empathic traits versus states [28] and why it can be important to account for context – including empathy for whom – when measuring empathy [29].

While this was not the initial goal of this study, we observed paradoxical results to the original and modified IRI constructs. When measuring Empathic Concern, students tended to report greater levels of dispositional concern than manifestations of such concern with their design team members. Conversely, when measuring Perspective-Taking, students tended to report greater levels of perspective-taking with/for team members when compared to their perspective-taking tendencies. In short, for both groups of students, some facets of the curriculum seemed to prompt perspective-taking while inhibiting empathic concern. To address this paradox, we hearken to Davis's [65] conception of ''antecedents'' of empathy. For empathy to manifest, individual (e.g., one's traits or dispositions) and situation (e.g., one's class or broader environment) factors must be salient. One example antecedent to empathic concern is valuing the welfare of others (see [66]) – thus, individuals who value others will be more likely to become empathically concerned towards others. Another antecedent may be the classroom or curriculum itself – building on the above section, an instructor who prompts empathy through empathy-adjacent activities may lead to greater levels of empathy regardless of learning modality. Thus, one way to assess empathy in large classes – such as this one – might start with measuring instructor empathy (or perhaps instructors' perceptions of the importance of empathy).

In a prior qualitative study, we found that students tended to talk about the ''collective'' (i.e., the whole team) when discussing empathy, so we postulated that empathy with/for team members represented a different phenomenon than collective empathy. First and foremost, the empathic [14] concern and perspective-taking constructs that we modified [71] focus on individual's empathy towards team members, whereas the collective empathy constructs [13] generally prompted the participant to reflect on the team from a holistic perspective. Consider the differences between the empathic concern with/for team members question, ''I often have tender, concerned feelings for my teammates,'' and the Affective Collective Empathy question, ''Our team members tend to get emotionally involved with others' feelings within our team.'' The latter question connotates a ''we'' perspective whereas the former starts with ''I.'' Thus, future work assessing empathy ought to consider the directionality of items and try to add greater specificity to *who* individuals may be empathizing with/for. In our study, EC_{team} and PT_{team} seem to measure empathy by the student towards team members, whereas the collective empathy constructs measure one's perception of empathy throughout the whole team.

Empathic Concern and Perspective-Taking are two specific empathy concepts [23], whereas the collective empathy constructs measure three empathy dimensions (Affective, Cognitive, and Behavioral, see Clark et al., [28]). Thus, the coverage of empathy is broader in Akgün's [13] measures. A more focused measure of empathy concepts [23] but from a collective perspective may have yielded different results in this study. For example, the EC_{team} item, ''I often have tender, concerned feelings for my teammates,'' might be revised to, ''My team members often have tender, concerned feelings for other team members.'' Such a question might rather be classified as Collective Empathic Concern (rather than Empathic Concern with/for Team Members).

Finally, while we did not find significant changes across Hybrid and Learning modalities, when we look across responses to the empathy constructs we utilized herein, we see noticeable differences. Firstly, Affective Collective Empathy was by far the lowest response for each group, with levels that were roughly neutral, whereas Perspective-Taking with/for team members was the highest empathic state for both groups. This may suggest that the curriculum itself purposefully (and, perhaps, successfully) fostered Perspective-Taking in the course. Alas, these responses reveal a lack of affective engagement within the team. Such a finding hearkens to the culture of disengagement in engineering [68]. Given the rise in research on empathy in engineering, we argue that a more concerted focus

on *affective* empathy offers one way to offset the culture of disengagement by encouraging instructors to emphasize not only cognitions, but also the role of emotions and feelings of others in engineering decision-making.

5.3 Limitations and Future Work

First, the time of this study was near the start of the pandemic. When students participated in classes, there was mandatory mask-wearing, instructors often enforced safety protocols (thus taking time away from instruction), there were many illnesses among students (and instructors), and miscellaneous life issues. Many of these issues were more pronounced for the Hybrid students (who were on-campus) when compared to online learners. Factors such as these might have influenced the lack of differences found herein. Thus, it is possible that replicating this study at a different point in time may yield distinct results.

Second, individuals from different socio-economic statuses and achievement-levels have had fundamentally different educational pandemic-related experiences [69]. Likewise, demographics such as gender can influence their levels of empathy [70]. We did not compare results by demographics in this study, but such factors may play a key role in empathy's manifestation.

Finally, this study was primarily quantitative, with some bits of qualitative data gathered via our course observations and a post-analysis discussion with the online instructor that we used to contextualize findings. More purposeful qualitative lines of inquiry would enhance the understanding of how empathy manifests across instructional contexts.

6. Conclusion

As empathy plays an important role in teamwork, it is important to know how empathy manifest within teamwork settings, how to help students develop its use in teams, and how to assess its manifestation. In this quantitative study, we explored how empathy manifested with/for team members in Hybrid versus Online instructional settings in the Fall 2021 academic semester. We addressed two research questions: (1) "To what extent are there differences in empathy with/for team members in hybrid versus online learning modalities?", and (2) "To what extent are there correlations between empathy constructs in hybrid and online learning modalities?" To address these questions, we collected responses to seven empathy constructs near the end of a first-year engineering design course. Two constructs were measures of "empathic traits" from a prominently used instrument in engineering, and the remaining five empathy constructs were measures of "empathic states" and incorporated items that had students reflect how empathy manifested with/for team members during their course design project. We hypothesized that students empathic states would be more prominent in Hybrid than Online learning settings, but we found no significant differences in our analysis. We computed and reviewed correlations between empathy constructs based on instructional modality and we observed trends that suggested empathic traits became empathic states to a slightly greater degree among Hybrid learners. Given the lack of significant findings, during the discussion we identified potential factors that influenced empathy across instructional settings, with a concerted focus on individual and situational antecedents factors. We also reflected on the instrument design and offered assessment considerations for measuring empathy in different ways. Taken together, we hope this study can improve efforts at promoting empathic formation, specifically empathy with/for team members, in engineering curriculums.

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