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Empathic creativity: can trait empathy predict creative concept generation and selection?

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Abstract

Over the past decade, engineering design research has seen a significant surge of the discussion of empathy. As such, design researchers have been devoted in devising and assessing empathic design activities. While prior research has examined the utility of empathic design experiences on driving creative concept generation, little is known about the role of a designer's empathic tendencies in driving creative concept generation and selection in an engineering design project. Without this knowledge, we cannot be sure if, when, or how empathy influences the design process. Thus, the main goal of this paper was to identify the role of trait empathy in creative concept generation and selection in an engineering design student project. In order to achieve this objective, a study was conducted with 103 first-year engineering students during two design stages of an 8-week design project (concept generation and concept selection). The main findings from this paper highlighted that empathic concern tendencies positively impacted the generation of more ideas while personal distress tendencies negatively impacted the generation of more ideas. During concept selection, perspective-taking tendencies positively impacted participants' propensity for selecting elegant ideas. This research took the first step in encouraging empirical investigations aimed at understanding the role of trait empathy across different stages of the design process.

Introduction

The ability to understand and feel the needs and circumstances of others, also known as empathy, has been found to help designers develop a deeper understanding of the design problems they solve (Walther *et al.*, 2012). Empathy could be particularly important in the early conceptual stages [i.e., concept generation and selection (Toh and Miller, 2016*a*)] of the design process (McGinley and Dong, 2011) as it involves a designer's attempt to "relate to [the user] and understand the situations and why certain experiences are meaningful to these [users]" (Battarbee, 2004, p. 67). As such, the design community has been invested in devising and assessing empathic design activities, such as simulating empathy evoking scenarios (Raviselvam *et al.*, 2016, 2017), in the design process (Lin and Seepersad, 2007; Strobel *et al.*, 2013; Raviselvam *et al.*, 2017; Surma-aho *et al.*, 2018*a*, 2018*b*; Tang, 2018). While empathy has been established as an essential component of design (McGinley and Dong, 2011; Walther *et al.*, 2012; Raviselvam *et al.*, 2016, 2017), the role of empathy on impacting creative design outcomes is still unclear, especially during concept generation and selection. Formalizing the role of empathy in these earlier conceptual stages can save costs and effort (Mattson and Messac, 2005), as the success of a product can be linked to the early conceptual stages of the idea's emergence (Goldenberg *et al.*, 2001), and being empathic in those stages can be gateway to creative solutions to the design problem (McGinley and Dong, 2011).

Empathy can be particularly important in the context of artificial intelligence (AI) since the main goal of using AI in design is to create better AI assistants that could help designers along the different stages of the design process (Gero, 2007). However, the "fuzzy front end" (Calabretta and Gemser, 2015) of the design process is challenging to translate into AI terms (Achiche *et al.*, 2013). In this fuzzy-front end, designers are involved in numerous decisions that require cognitive effort (Toh and Miller, 2019). Understanding *if* and *how* empathy is important in that fuzzy-front end, particularly during concept generation and selection, is critical in order to better build AI assistants.

At its current state, the literature identifying the role of empathy in design is in conflict. A group of researchers, see Hess *et al.* (2015), Hess and Fila (2016), Genco *et al.* (2011), Johnson *et al.* (2014), and Raviselvam *et al.* (2016, 2017), are advocating for the role of empathy in design and are invested in devising empathy invoking interventions, particularly at the concept generation stage. In contrast, other researchers (Mattelmäki *et al.*, 2014) warn designers from engaging in empathic design activities, as these empathy invoking activities might end up in the "empathy trap"; their attempt to be empathic might trigger popular *directed* reflections from the users instead of providing radical innovations to the existing problems (Mattelmäki *et al.*, 2014).

While the prior work investigating the role of empathy in concept generation is in conflict, the role of empathy during concept selection has been *scarcely* researched. This is problematic since the concept selection stage is when designers narrow down the ideas generated during concept generation (Toh and Miller, 2016*a*) and has been identified as one of the most critical stages that determine successful design (Pugh, 1996; Rietzschel *et al.*, 2010). Studying designers' creativity during concept generation *solely* is not representative of the designers' creativity since the "availability of creative ideas is a necessary but insufficient condition for innovation" (Rietzschel *et al.*, 2006, p. 48).

Taken as a whole, prior work investigating the relationship between empathy and creative design outcomes during concept generation provides conflicting interpretations. Additionally, the role of empathy in concept selection has been scarcely researched. Thus, formalizing the role of an individual's trait empathy in driving design outcomes in the concept generation and selection stages of the design process could bring great clarity to the existing research. Without this knowledge, the design community cannot be sure *if*, *when*, or *how* empathy is important in the design process. As such, the main goal of this paper is to identify the role of trait empathy in creative concept generation and selection in an engineering design student project. The results from this research can form the basis of computational models in design.

Related work

In order to establish the framework for the current investigation, this section highlights prior work on (1) the role of empathy in engineering design and (2) measuring trait empathy, which serve as the basis for the current study.

The role of empathy in the design process

Empathy has been defined commonly in the psychology literature as, "a social and emotional skill that helps us feel and understand the emotions, circumstances, intentions, thoughts, and needs of others such that we can offer sensitive, perceptive, and appropriate communication and support" (McLaren, 2013). Empathy has been identified by psychologists as an emotional intelligence skill (Riemer, 2003; McDonald and Messinger, 2012; Tekerek and Tekerek, 2017) that allows individuals to distinguish and deal with others successfully (Badea and Pană, 2010). Notably, the psychology literature discretizes empathy into the following two components: a cognitive component and an affective component (Duan and Hill, 1996; see Figure 1). The cognitive component indicates that one's empathy is dependent on the situation, while the affective component characterizes one's empathy as an emotional response (Duan and Hill, 1996), see Figure 1 (Hess and Fila, 2016). Hoffman (1977), Shantz (1975), and Strayer (1987) view empathy to involve both cognitive and affective components. According to Batson (2009), there are eight components to empathy, including the following: knowing another person's internal state; imagining how others think and feel; intuiting or projecting oneself into another's feeling distress at witnessing another person's suffering; and feeling for another person who is suffering (Batson, 2009).

Notably, some scholars have considered empathy as a personality trait or general ability (Kerr, 1947; Danish and Kagan, 1971; Buie, 1981; Hoffman, 1982; Davis, 1983; Book, 1988). For example, Davis (1983) believed that empathy is a dispositional trait, or a stable ability. On the same line of research, there has been a discussion in the literature that the basis of empathic thinking is heritable (Melchers *et al.*, 2016) with behavioral and imaging genetic studies providing evidence for a genetic basis for empathy (Anckarsäter and Cloninger, 2007; Knafo *et al.*, 2008, 2009; Chakrabarti and Baron-Cohen, 2013; Melchers *et al.*, 2016). However, researchers argue that the environmental context could impact an individual's empathy (Knafo *et al.*, 2008, 2009; Abramson *et al.*, 2020), highlighting the role of particular parental contexts in promoting prosocial behavior (Fortuna and Knafo, 2014). Furthermore, other researchers have also reported that mental health was found to be related to an individual's empathic behavior (Knafo *et al.*, 2009; Apter-Levy *et al.*, 2013; Mitchell *et al.*, 2021).

In the context of engineering design, empathy has been found to help designers better understand the needs of users that are different from themselves (Gray *et al.*, 2015; Schmitt & Morkos). Prior research in engineering design has shown that developing empathy can help develop a deeper understanding of the design problem (Walther *et al.*, 2012) and the stakeholders (Schmitt & Morkos) and encouraged an employment of a more targeted user research (Gray *et al.*, 2015). In a qualitative study, Fila and Hess (2016) found empathy to be positively related to engineering students' problem contextualization and individual design inspiration.

In terms of design effectiveness, Genco *et al.* (2011) and Johnson *et al.* (2014) found that empathetic design experiences were effective in driving creative outcomes (originality and quality) in the conceptual design stages. On the same line of research, simulating extraordinary user scenarios was effective in enhancing

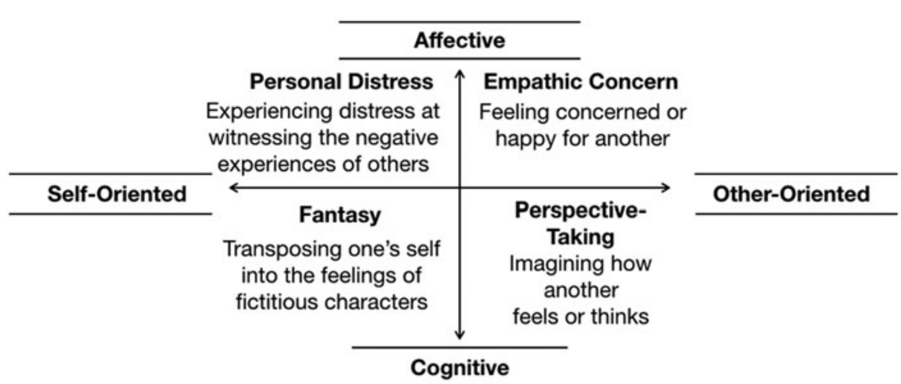

Fig. 1. A summary of the cognitive and affective processes involved in the four interpersonal reactivity subscales from Davis (1980).

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students' empathic self-efficacy as well as the novelty, quantity, and variety of ideas generated by students (Raviselvam *et al.*, 2016). While prior work found a relationship between empathy and creativity, researchers have found that the creativity of solutions generated by a designer can hinge on the nature of the design task (Starkey *et al.*, 2016), and the designer's personal connection with the end-user (Raviselvam *et al.*, 2017). Similarly, Hess and Fila (2016) explored designers' selection of empathic techniques in two design tasks: a service-learning course and a decontextualized design problem; they found that students in the service-learning course made use of a higher variety of other-oriented empathic techniques which suggested the significance of the context of the design problem in impacting design outcomes, which this work controlled for.

In contrast to the previous research that highlighted the effectiveness of empathic design techniques in the concept generation stage, engagement in empathic design experiences have also received criticism in the literature. For example, Chung and Joo (2017) found that engaging designers with an empathic instruction task (watching a video on the end-user) decreased their concept evaluation scores, suggesting a "dark" side to empathy. Breithaupt (2019) discusses some of the dark sides of empathy, empathic vampirism, where individuals might over-identify with others, without necessarily having the best interests of those others in mind (Breithaupt, 2018). In the context of design, that line of research suggests that the designer would end up designing for themselves if they over empathize (Breithaupt, 2018).

While this prior work provides conflicting interpretations on the role of empathy in concept generation, little research has explored the role of empathy in concept *selection*. During this stage, designers narrow down the ideas generated during concept generation (Toh and Miller, 2016*a*). Studying designers' creativity during concept generation *solely* is not representative of the designers' creativity since generating creative ideas does not necessarily guarantee the final design's creativity (Rietzschel *et al.*, 2010). One way of assessing designers' creativity in the concept selection stage is through their propensity for selecting creative ideas (Toh and Miller, 2015, 2016b; Zheng *et al.*, 2018). While concept selection has been found to be an important component of creativity of the design process (Rietzschel *et al.*, 2006) that requires a different cognitive skillset that concept generation (Toh and Miller, 2019), the relationship between empathic tendencies and creative concept selection has not been established in the literature.

This existing research provides conflicting interpretations on the role of empathy in design and the scarcity of research on the role of empathy in concept selection. Therefore, formalizing the role of an individual's trait empathy in driving design outcomes in the earlier conceptual stages (e.g., concept generation and selection) of the design process could bring great clarity to the existing research. Without this knowledge, we cannot be sure *if*, *when,* or *how* empathy is important in the design process.

Measuring trait empathy

Trait empathy can be defined as "the reactions of one individual to the observed experiences of another" (Davis, 1983, p. 113). Trait empathy is broken down into a cognitive component and an affective component (Duan and Hill, 1996). The cognitive component defines an individual's empathy as dependent on the situation, while the affective component characterizes an individual's empathy by their emotional response and feeling (Shantz, 1975; Strayer, 1987; Duan and Hill, 1996).

One of the widely used measures of trait empathy is Davis' Interpersonal Reactivity Index (IRI; Davis, 1980). The IRI defines trait empathy with four empathic tendencies: (1) perspective-taking measures the ability "to adopt the perspectives of other people and see things from their point of view" (Davis, 1980, p. 12); (2) fantasy measures "the tendency to transpose themselves imaginatively into the feelings and actions of fictitious characters in books, movies, and plays" (Davis, 1980, p. 12); (3) empathic concern measures "the degree to which the respondent experiences feelings of warmth, compassion and concern for the observed individual" (Davis, 1980, p. 12); and (4) personal distress measures an "individual's own feelings of fear, apprehension and discomfort at witnessing the negative experiences of others" (Davis, 1980, p. 12).

While there are numerous instruments for assessing trait empathy (Davis, 1980; Baron-Cohen and Wheelwright, 2004), IRI is one of the few measures in the literature that encompasses both the cognitive and affective components of empathy (Duan and Hill, 1996). In engineering design, Hess and Fila (2016) argued that both components are needed to allow designers to better understand the end-users' needs. While IRI has been used in prior work to assess the empathic tendencies of engineering students (Hess *et al.*, 2016; Surma-aho *et al.*, 2018*b*), it has not been used in relation to creative concept generation and selection. Due to its rigorous development and acceptance in diverse communities of research, this study used IRI (Davis, 1980) to model designers' trait empathy and examine its relationship with driving designers' creative design outcomes.

Research objectives

Based on this prior work, the main objective of this study was to determine if or how engineering student trait empathy impacts their ability to generate and select creative concepts in an engineering design project, see Figure 2. Specifically, the following research hypotheses were devised:

h_1: Participants with higher trait empathy would generate more ideas.

h_2: Participants with higher trait empathy would generate more creative concepts.

h_3: Participants with higher trait empathy would select more creative ideas.

These hypotheses are based on prior work with engineering graduate students that found that trait empathy was related to their innovative self-efficacy (Surma-aho *et al.*, 2018*b*).

Methodology

In order to answer this research objective, a study was conducted with 103 first-year engineering design students who were in four sections of an introduction to engineering design course taught by three instructors at a large Northeastern university in the United States. The remainder of this section summarizes the methodological approach taken in this study.

Participants

Participants were recruited from four sections of an introduction to engineering design course taught by three instructors at a large Northeastern university. Notably, the first-year course studied has received national awards due to its ability to successfully

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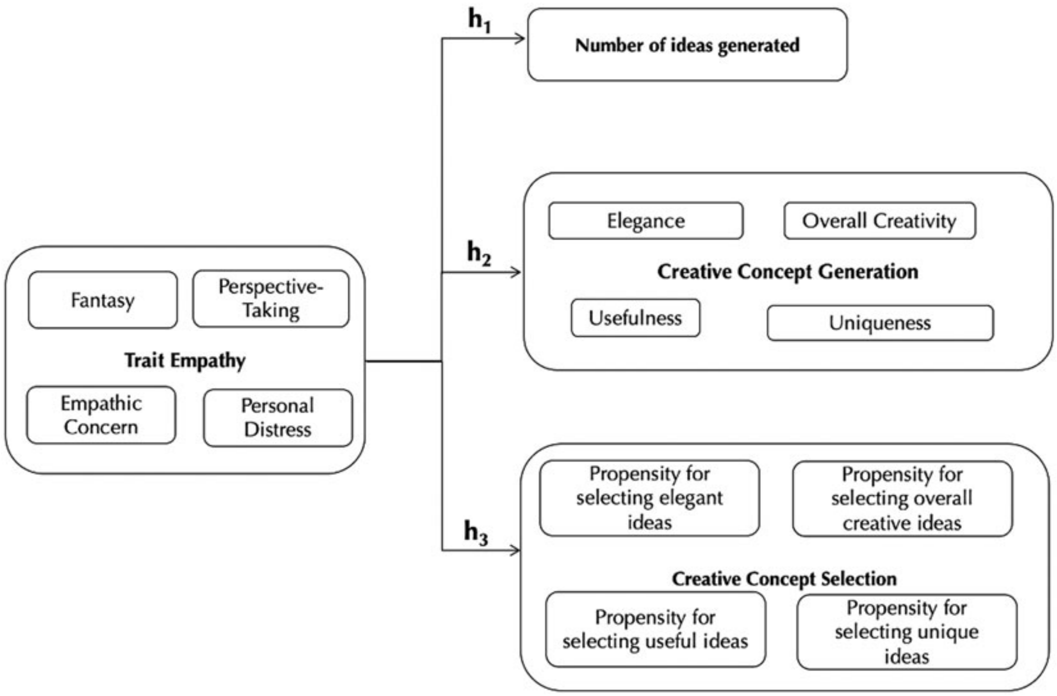

Fig. 2. Theoretical framework.

incorporate team-based projects (Ritter and Bilen, 2019). In all, 103 first-year engineering design students (73 males and 30 females) participated in the study.

Procedure

The study was completed over the course of an 8-week design project that included the following design stages: (1) Introduction to the Design Process and Team Formation, (2) Problem Formulation and Customer Needs Assessment, (3) Idea Generation, (4) Concept Selection, (5) Detailed Design, Manufacturing & Prototyping, and (6) Final Design. Thus, the data presented here is part of a larger data collection effort geared at understanding the role of empathy in engineering design education (Alzayed, 2019). However, only the aspects of the study pertinent to the current investigation (concept generation and concept selection) are described here.

At the start of the semester, the researchers presented the study to each of the four sections of the course according to the Institutional Review Board guidelines set forth at the university. Participation in the study was voluntary, and informed consent was gathered prior to the start of the study. Participants were then divided into 3–4-member design teams by the course instructor in their respective sections, and they were assigned the eight-week design project. The project focused on addressing the United Nation's Sustainable Development Goal 3 (Nam, 2015), which aims at "ensuring healthy lives and promoting well-being for all at all ages." Specifically, teams were asked to select between the following challenges: (1) lack of safe water, sanitation, and hygiene services, (2) access to hepatitis-B vaccinations, (3) indoor and ambient air pollution, and (4) road traffic injuries. While participants in all four sections were allowed to select from these four design challenges, the design context of these challenges varied across the sections. Specifically, two of the sections focused on designing for the *developed* world ($n = 50$ participants), while the remaining two sections were tasked with designing for the *developing* world ($n = 53$ participants) [see "Problem Statements - Sustainable Development Goal 3" (2020) for the detailed problem statements].

The participants then continued to work on the project per the timeline presented in Figure 3. In week 1, participants were asked to complete an extreme user research activity where they were encouraged to use reputable online sources to develop a 1–2-page memo about their chosen user group. In week 2, as a team, participants completed an empathy map (Ferreira *et al.*, 2015) using the information they gathered in their user research. Teams were encouraged to answer the following questions: (1) what does the user say? (2) what does your user think? (3) how does your user act? and (4) how does your user feel? Next, participants were tasked with developing personas for their intended user and formulating point-of-view statements (Dam and Teo, 2017). Toward the end of week 2, participants were tasked with creating a journey map to help them visualize key moments in the daily life of the user (Howard, 2014).

During the concept generation stage (week 4), participants were involved in two brainstorming sessions: reverse brainstorming (Hagen *et al.*, 2016), where they were given 15 min to brainstorm bad ideas that would make the problem worse; and then individual brainstorming where they were asked to generate concepts for 20 min. Specifically, participants were asked to come up with as many ideas as possible by completing idea generation cards (see Fig. 4 for example). Participants were asked to sketch the idea in addition to writing a short description of the idea. This form of task during idea generation has been used in prior studies in design research (Starkey *et al.*, 2016; Toh and Miller, 2016*a*; Miller *et al.*, 2021).

During the concept selection stage (week 5), participants were asked to individually filter out the concepts generated by their team by completing a concept screening matrix where they

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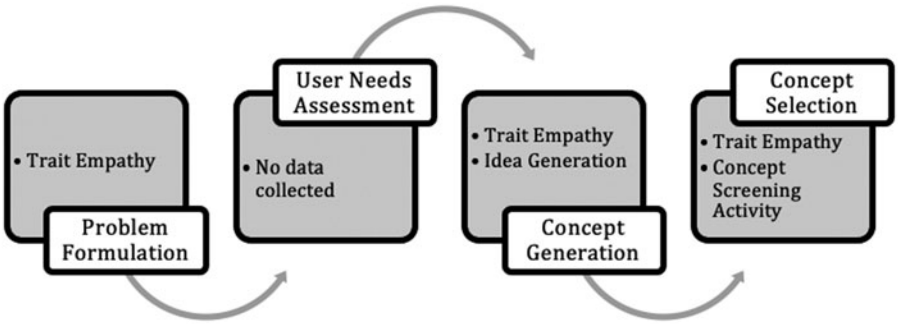

Fig. 3. Timeline of the project.

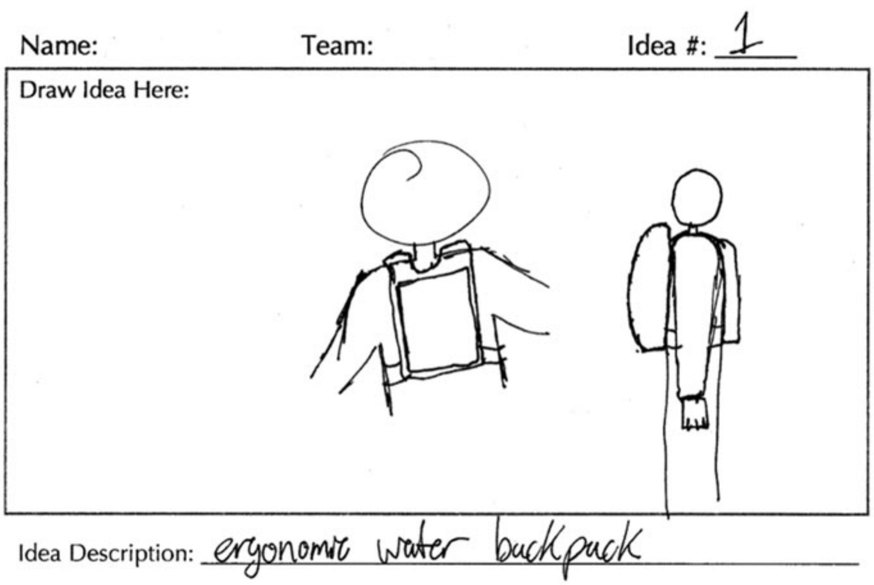

Fig. 4. An example of an idea generation card completed by participant 32.

categorized each idea as "consider" or "do not consider." Ideas falling in the "consider" category are ideas that will most likely satisfy the design goals and that they would like to prototype immediately (Toh and Miller, 2015, 2016*a*, 2016*b*). Meanwhile, ideas that fall under the "do not consider" category have little to no likelihood of satisfying the design goals and you fin minimal value in these ideas (Toh and Miller, 2015, 2016*a*, 2016*b*).

Finally, in weeks 6–8, participants were asked to prototype their solutions and report their final conceptual design in a written report. Of importance to the current study, participants were asked to complete the 28-item Trait Empathy survey (see "Metrics") at the end of week 4, immediately after the concept generation activity, and at the beginning of week 5, immediately after the concept selection activity. The survey was completed electronically in-class via Qualtrics.

Metrics

In order to explore the factors critical to achieving the research objective, the following metrics were used:

Trait Empathy: Participants' trait empathy was measured using the IRI (Davis, 1980), a 28-item survey answered on a 5-point Likert scale ranging from "does not describe me well" to "describes me very well." This instrument assesses an individual's cognitive and affective components of their empathy (Duan and Hill, 1996); those two components have been deemed as necessary to understand the users' needs in engineering design (Hess and Fila, 2016). The instrument was utilized in prior research in assessing the empathic tendencies of engineering students (Hess *et al.*, 2015, 2016; Surma-aho *et al.*, 2018*b*). The IRI includes four subscales (perspective taking, fantasy, empathic concern, and personal distress) each made up of seven different items. For example, an item in empathic concern is "I often have tender, concerned feelings for people less fortunate than me." Due to previous research that shows that trait empathy changes between the design stages (concept generation, concept selection) (Alzayed *et al.*, 2021), we have tested the hypotheses with participants' empathy at those different time points.

The four-factor structure of the IRI has been validated (Davis, 1983) and has been implemented to assess individuals' empathic tendencies (Siu and Shek, 2005; Péloquin and Lafontaine, 2010; Kokkinos and Kipritsi, 2012; Gilet *et al.*, 2013), including engineering students (Hess *et al.*, 2015, 2016; Surma-aho *et al.*, 2018*b*). A reliability analysis was conducted to evaluate the internal reliability of the subscales of the IRI, and a high Cronbach's α was observed for fantasy (problem formulation $\alpha = 0.82$, concept generation $\alpha = 0.83$, and concept selection $\alpha = 0.91$), perspective-taking (problem formulation $\alpha = 0.76$, concept generation $\alpha = 0.78$, and concept selection $\alpha = 0.82$), empathic concern (problem formulation $\alpha = 0.77$, concept generation $\alpha = 0.80$, and concept selection $\alpha = 0.80$), and personal distress (problem formulation $\alpha = 0.78$, concept generation $\alpha = 0.83$, and concept selection $\alpha = 0.85$).

Number of Ideas: The number of ideas was calculated for each participant by counting the number of idea sheets completed by

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each participant during the individual brainstorming session. This aligns with the quantity metric from the work of Shah, Vargas-Hernandez, and Smith (Shah *et al.*, 2000).

Consensual Assessment Technique (CAT): The Consensual Assessment Technique (Amabile, 1983) was used to assess the effectiveness of the ideas generated by the 103 participants. This technique has been widely used in prior research in engineering design (Christiaans and Venselaar, 2005; Nikander *et al.*, 2014) and has been identified as a global measure of creativity (Fischer, 2013; Cseh and Jeffries, 2019). The CAT defines that an idea is creative when judges *independently* agree that it as creative (Amabile, 1982). Using a 6-point Likert Scale, the ideas were rated on the following criteria: overall creativity, usefulness, uniqueness, and elegance (Besemer and O'Quin, 1999). Specifically, (1) overall creativity relates to experts' judgment of the overall creativity of an idea, (2) uniqueness relates to overall perceptions of how original and surprising the idea was (Besemer and O'Quin, 1999), (3) usefulness relates to the overall perceptions of value, logic, and how understandable the ideas were, while (4) elegance refers to the idea's "simplicity, insight shown, and conciseness of [the idea's] presentation" (Besemer and O'Quin, 1999, p. 288) The four metrics have been previously used in design research to assess ideation effectiveness (Klein *et al.*, 2006; Buelin-Biesecker and Wiebe, 2013; Sinha *et al.*, 2017; Cseh and Jeffries, 2019; Prabhu *et al.*, 2019; Zheng and Miller, 2019). Additionally, we asked the raters to rate the drawing abilities possessed by each idea to control for that factor, since drawing abilities have been found to influence ratings of creativity (Chan and Chan, 2007).

The CAT method uses experts to rate 20% of the complete idea set to provide a training set for quasi-experts to rate the remaining set based on the experts' mindset in rating the ideas (Kaufman and Baer, 2012; Cseh and Jeffries, 2019). Two faculty members experienced in engineering design research independently rated 20% of the ideas. Additionally, two quasi-experts (PhD candidate and third-year undergraduate student, both studying Industrial Engineering) independently rated the 20% overlap of ideas to ensure agreement with the expert judges (Landis and Koch, 1977). Each of the quasi-experts' ratings had high agreement ($\alpha > 0.7$) (Koo and Li, 2016) with the expert raters on each of the five metrics, see Table A1 in the Appendix.

Once inter-rater reliability was achieved, the two quasi-experts rated the remaining 80% of the ideas independently and high inter-rater reliability ($\alpha > 0.7$) (Koo and Li, 2016) was achieved between the two quasi-expert raters for each of the five metrics, see Table A1 in the Appendix. An average of the scores from the two quasi-expert raters was calculated for each metric (overall creativity, elegance, usefulness, uniqueness, and drawing abilities), as per recommendations by Silvia (2011); see Figure 5a,b for examples of ratings.

Propensity for Selecting Creative Ideas: To assess simulated teams' propensity for selecting creative concepts, we used the propensity to ward creative concept selection metric, P_C (Toh and

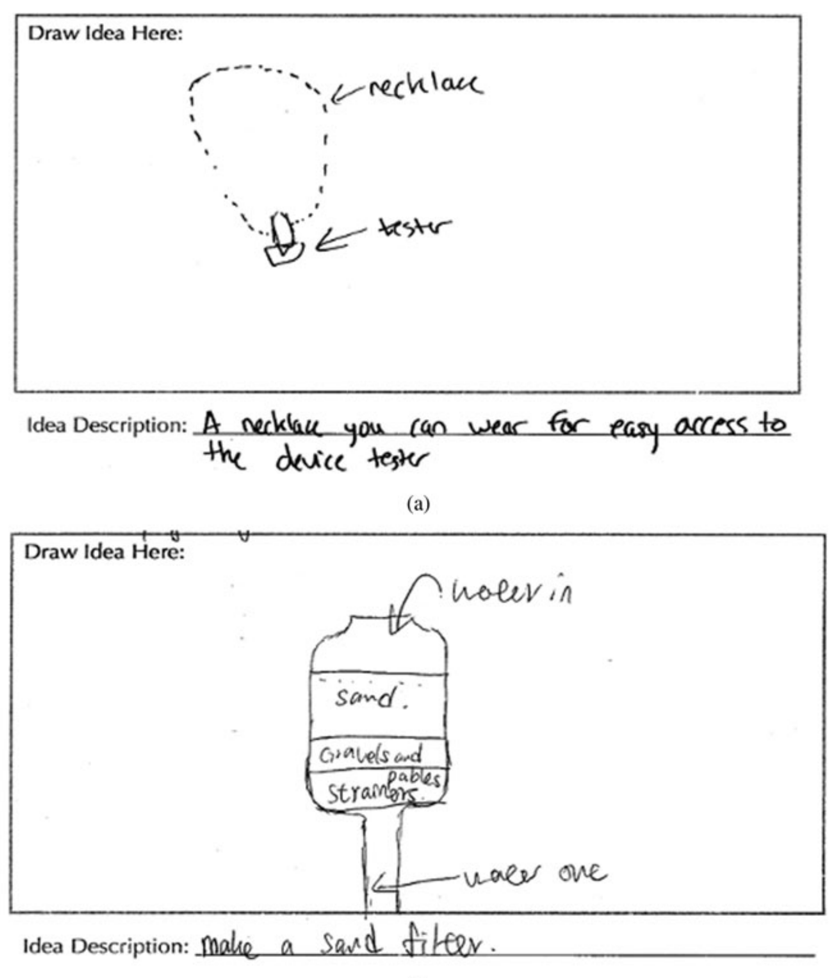

Fig. 5. (a) An idea from participant 53 that received a score of 4 on overall creativity, 3 on usefulness, 5 on uniqueness, 4 on elegance, and 3 on drawing abilities. (b) An idea from participant 81 that received a score of 1 on overall creativity, 3.5 on usefulness, 1 on uniqueness, 3 on elegance, and 4 on drawing abilities.

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Miller, 2015), a metric that has been used in engineering design research (Toh and Miller, 2015, 2016*b*; Zheng *et al.*, 2018). Specifically, P_C measures the "…tendency towards selecting (or filtering) creative concepts during the concept selection process" (Toh and Miller, 2015, p. 118). For instance, the formula to calculate participants' propensity toward selecting unique concepts ($P_{\text{Uniqueness}}$) can be summarized as the following:

$$P_{\text{Uniqueness}} = \frac{\text{average uniqueness of selected concepts}}{\text{average uniqueness of generated concepts}}.$$

Similarly, an individual's propensity toward concept selection of ideas rated high in (1) overall creativity, (2) usefulness, (3) elegance, and (4) drawing abilities was also assessed in the same manner. For example, an individual can receive a value ($P_{\text{Uniqueness}}$) greater than 1 if the average uniqueness of the selected ideas is higher than the average uniqueness of the available ideas, indicating a propensity for selecting unique ideas, while a value on $P_{\text{Uniqueness}}$ that is less than 1 indicated an aversion for selecting unique concepts (Toh and Miller, 2015). Toh and Miller's paper (2015) provides further details on the scoring methodology.

Data analysis and results

In order to answer the research objective, statistical analyses were computed using SPSS 25.0, and a significance level of 0.05 was used in all analyses. The results are presented as mean ± standard error (SE) unless otherwise denoted. In addition, effect sizes were classified according to Cohen (1988). The data used in the analyses of the three research questions is available upon request, and a sample of the data used in these analyses is presented in Tables A1–A3 in the Appendix.

Hypothesis 1: participants with higher trait empathy would generate more ideas

Our first research hypothesis was that trait empathy would be positively related to the generation of more ideas (Duncan *et al.*, 2003; Roberge, 2013; Surma-aho *et al.*, 2018*b*). To address this research hypothesis, a hierarchical regression model was computed with the dependent variables being the number of ideas generated by each participant. In addition, since the design context, design problem, and course instructor have been shown to influence creativity (Alsager Alzayed *et al.*, 2020, Alzayed *et al.*, 2021), we controlled for these factors as they were not the focus of the current investigation. To account for this, the independent variables were entered in two blocks: (i) design context (developing, developed), course instructor, and design problem, and (ii) perspective-taking, fantasy, empathic concern, and personal distress. A visual schematic of the hierarchical regression analyses used for this RQ is shown in Figure 6.

Prior to the analysis, statistical assumptions were checked. The results showed linearity of the independent variables as assessed by partial regression plots and a plot of studentized residuals against the predicted values. Visual inspection of a plot of studentized residuals revealed that the assumption of homoscedasticity was met. There was no multicollinearity in the independent variables, as assessed by tolerance values greater than 0.1 (Fox, 1991). As assessed by the studentized deleted residuals greater than ±3 standard deviations, there were 4 outliers. The outliers were found to have no significant impact on the significance of the results and, therefore, the full analysis is presented here. Additionally, there were no leverage values greater than 0.2 (Huber, 1981), and no values for Cook's distance above 1 (Cook and Weisberg, 1982). Finally, normality was confirmed by visually inspecting the histograms and Q-Q plots. Based on these results, the analysis proceeded as planned.

The results from the hierarchical regression model showed that the design context and problem, and the course instructor, significantly predicted number of ideas, $R^2 = 0.124$, $F(3, 98) = 4.48$, $p < 0.01$, which is considered a small effect. However, the design context and problem, as well as the course instructor did not significantly contribute to the model, $p > 0.05$, see Table 1. The addition of trait empathy (fantasy, perspective-taking, personal distress, and empathic concern) to this model also led to a statistically significant model $F(7,98) = 2.99$, $p < 0.01$, with an R^2 change of 0.063. From the four empathic tendencies, *only* personal distress ($p = 0.047$) and empathic concern ($p = 0.037$) significantly contributed to the model. Specifically, personal distress negatively impacted the number of ideas generated by participants, while empathic concern positively impacted the number of ideas generated by participants.

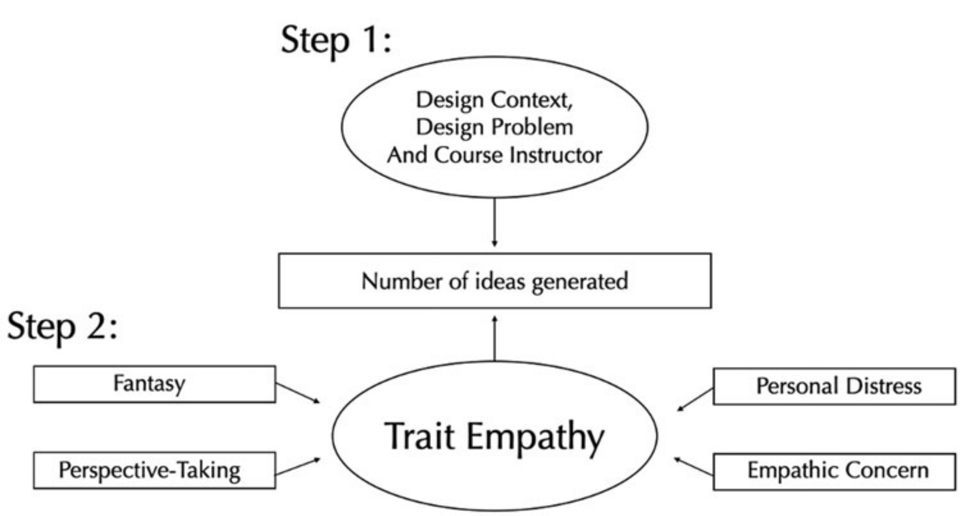

Fig. 6. Schematic representation of the two-step hierarchical regression model for RQ1.

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Table 1. Summary statistics of the regression model on the relationship between the number of ideas and trait empathy

Step	Factor		*B*	*SE*	β	*p*
1	Context		1.664	1.058	−0.029	0.900
	Problem		−0.204	1.612	−0.002	0.982
	Instructor		−0.007	0.320	0.379	0.119
2	Context		0.559	1.640	0.080	0.734
	Problem		0.041	0.325	0.014	0.900
	Instructor		1.162	1.093	0.264	0.291
	Trait Empathy	Fantasy	−0.005	0.066	−0.008	0.945
		Personal Distress	−0.139	0.069	−0.209	0.047
		Perspective-Taking	−0.108	0.089	−0.139	0.227
		Empathic Concern	0.169	0.080	0.242	0.037

The findings from this research question partially support our hypothesis that trait empathy positively impacted the number of ideas generated during concept generation. Empathic concern positively impacted the number of ideas generated by participants. This finding partially corroborates a qualitative investigation with engineering students (Fila and Hess, 2016) that found that empathic concern tendencies motivated students to work harder on an engineering task. However, personal distress was found to impact the number of the ideas generated by the participants, while perspective-taking and fantasy tendencies did not have an impact on the number of ideas generated. This finding is congruent to the discussion in the literature that note how being empathic may restrict the designer from coming up with creative innovations to the existing problem (Mattelmäki *et al.*, 2014).

Hypothesis 2: participants with higher trait empathy would generate more creative concepts

While the first research hypothesis investigated the impact of trait empathy on the number of ideas generated by participants, the second research hypothesis was that trait empathy would be positively related to the generation of ideas that are rated high in overall creative, elegant, useful, or unique ideas (Duncan *et al.*, 2003; Roberge, 2013; Surma-aho *et al.*, 2018*b*). To address this research hypothesis, four hierarchical regression models were computed with the dependent variables being the average overall creativity, average elegance, average usefulness, and average uniqueness of the teams' generated ideas. In addition, since the design context, design problem, and course instructor have been shown to influence creativity (Alsager Alzayed *et al.*, 2020, Alzayed *et al.*, 2021), we controlled for these factors as they were not the focus of the current investigation. Additionally, we controlled for the drawing abilities of each participant as the drawing abilities have been found to influence ratings of creativity (Chan and Chan, 2007). To account for this, the independent variables were entered in two blocks: (i) participant's average drawing abilities, design context (developing, developed), course instructor, and design problem, and (ii) perspective-taking, fantasy, empathic concern, and personal distress. A visual schematic of the hierarchical regression analyses used for this RQ is shown in Figure 7.

Prior to the analysis, statistical assumptions were checked. The results showed linearity of the independent variables as assessed by partial regression plots and a plot of studentized residuals against the predicted values. Visual inspection of a plot of studentized residuals revealed that the assumption of homoscedasticity was met. There was no multicollinearity in the independent variables, as assessed by tolerance values greater than 0.1 (Fox, 1991). As assessed by the studentized deleted residuals greater than ±3 standard deviations, there were 0, 6, 4, and 1 outliers for the first, second, third, and fourth regression models, respectively. The outliers were found to have no significant impact on the significance of the results and, therefore, the full analysis is presented here. Additionally, there were no leverage values greater than 0.2 (Huber, 1981), and no values for Cook's distance above 1 (Cook and Weisberg, 1982). Finally, normality was confirmed by visually inspecting the histograms and Q-Q plots. Based on these results, the analysis proceeded as planned.

The results from all four hierarchical regression models showed that participant's average drawing abilities, design context (developing, developed), course instructor, and design problem, and (ii) perspective-taking, fantasy, empathic concern, personal distress all did not significantly predict overall creativity, $p > 0.05$. These results indicated that trait empathy did not predict the overall creativity, usefulness, uniqueness, and elegance of the generated ideas.

The results from this research question refute our hypothesis that trait empathy would be related to creative idea generation. While the results from the first research question indicated that trait empathy predicted the number of ideas, it did not necessarily predict the creativity of those ideas. Specifically, all four empathic tendencies (perspective-taking, fantasy, empathic concern, and personal distress) failed to predict the overall creativity, usefulness, uniqueness, and elegance of the generated ideas. These results resonate with prior work that discussed varying points of views (Genco *et al.*, 2011; Johnson *et al.*, 2014; Breithaupt, 2019) on the role of empathy in concept generations, whereby we find evidence that supports the notion of the utility of empathy on the number of ideas generated, but the null impact it had in terms of the creativity of those generated ideas.

Hypothesis 3: participants with higher trait empathy would select more creative ideas

The third research hypothesis was that trait empathy would be positively related to the selection of overall creative, elegant, useful, and unique ideas. To address this research hypothesis, four hierarchical regression models were computed with the dependent

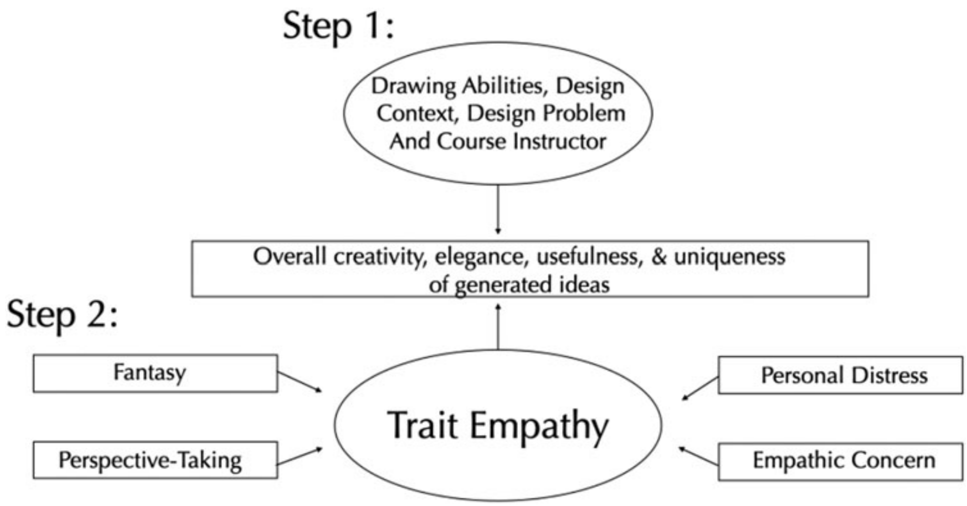

Fig. 7. Schematic representation of the two-step hierarchical regression model for RQ2.

variables being participants' propensity for selecting (1) overall creative, elegant, (2) useful, and (3) unique ideas. In addition, since the design context, design problem, and course instructor have been shown to influence creativity (Alsager Alzayed *et al.*, 2020, Alzayed *et al.*, 2021), we controlled for these factors as they were not the focus of the current investigation. Additionally, we controlled for teams' propensity for selecting ideas that are rated high in drawing abilities since prior research found that the drawing abilities portrayed in a design could have a potential impact on an individual's perception of the creativity of that design (Chan and Chan, 2007). To account for this, the independent variables were entered in two blocks: (i) the propensity for selecting ideas rated high in drawing abilities, design context (developing, developed), course instructor, and design problem, and (ii) trait empathy (perspective-taking, fantasy, empathic concern, and personal distress). A visual schematic of the hierarchical regression analyses used for this RQ is shown in Figure 8.

Prior to the analysis, statistical assumptions were checked. The results showed linearity of the independent variables as assessed by partial regression plots and a plot of studentized residuals against the predicted values. Visual inspection of a plot of studentized residuals revealed that the assumption of homoscedasticity was met. There was no multicollinearity in the independent variables, as assessed by tolerance values greater than 0.1 (Fox, 1991). As assessed by the studentized deleted residuals greater than ±3 standard deviations, there were 4, 5, 3, and 3 outliers for the first, second, third, and fourth regression models, respectively. The outliers were found to have no significant impact on the significance of the results and, therefore, the full analysis is presented here. Additionally, there were no leverage values greater than 0.2 (Huber, 1981), and no values for Cook's distance above 1 (Cook and Weisberg, 1982). Finally, normality was confirmed by visually inspecting the histograms and Q-Q plots. Based on these results, the analysis proceeded as planned.

The results from the first hierarchical regression model showed that only drawing abilities, but not design context and problem, nor the course instructor, significantly predicted the propensity for selecting *overall creative* ideas, $R^2 = 0.260$, $F(4, 89) = 8.34$, $p < 0.01$, which is considered a medium effect. The addition of

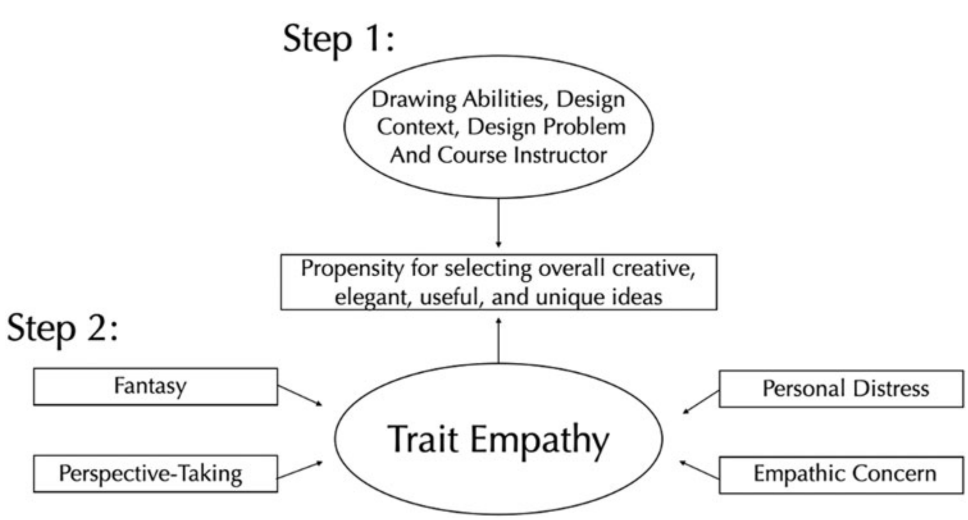

Fig. 8. Schematic representation of the two-step hierarchical regression model for RQ3.

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Table 2. Summary statistics of the regression model on the relationship between participants' propensity for selecting elegant ideas and trait empathy (* indicates significant results)

Step	Factor		*B*	*SE*	β	*p*
1	Propensity for selecting ideas rated high in drawing abilities		0.733	0.118	6.228	<0.01*
	Context		0.009	0.078	0.110	0.913
	Problem		0.001	0.015	0.040	0.968
	Instructor		−0.026	0.051	−0.496	0.621
2	Propensity for selecting ideas rated high in drawing abilities		0.750	0.119	6.328	<0.01*
	Context		−0.003	0.078	−0.041	0.967
	Problem		0.002	0.015	0.155	0.877
	Instructor		−0.028	0.051	−0.538	0.592
	Trait Empathy	Fantasy	0.002	0.015	0.155	0.877
		Personal Distress	−0.028	0.051	−0.538	0.592
		Perspective-Taking	0.009	0.004	2.254	0.027*
		Empathic Concern	0.000	0.003	0.093	0.926

trait empathy (fantasy, perspective-taking, personal distress, and empathic concern) to this model also led to a statistically significant model $F(8,89) = 4.51$, $p < 0.01$, with an R^2 change of 0.022; however, all of the perspective-taking, fantasy, empathic concern, and personal distress, all did not contribute to the model, $p > 0.05$.

While the first regression model investigated the role of empathy on the propensity for selecting overall creative ideas, the second hierarchical regression model investigated the role of trait empathy on the propensity for selecting *elegant* ideas. The results from the second hierarchical regression model showed that only drawing abilities, but not design context and problem, nor the course instructor, significantly predicted the propensity for selecting *elegant* ideas, $R^2 = 0.345$, $F(4, 89) = 11.18$, $p < 0.01$, which is considered a medium effect. The addition of trait empathy (fantasy, perspective-taking, personal distress, and empathic concern) to this model also led to a statistically significant model $F(8,89) = 6.420$, $p < 0.01$, with an R^2 change of 0.043. Specifically, perspective-taking tendencies ($p = 0.027$) positively predicted participants' propensity for selecting elegant ideas. All other empathic tendencies did not significantly contribute to the model, see Table 2 for a summary of the regression statistics.

The results from the third hierarchical regression model showed that the design context and problem, and the course instructor, significantly predicted the *usefulness* of the generated ideas, $R^2 = 0.599$, $F(4,89) = 31.77$, $p < 0.01$, which is considered a large effect. However, the design context and problem, as well as the course instructor did not significantly contribute to the model, $p > 0.05$. The addition of trait empathy (fantasy, perspective-taking, personal distress, and empathic concern) to this model also led to a statistically significant model $F(8,89) = 16.82$, $p < 0.01$, with an R^2 change of 0.025; however, all of the four empathic tendencies, fantasy, perspective-taking, personal distress, and empathic concern, did not significantly contribute to the model, $p > 0.05$.

Finally, the fourth hierarchical regression model investigated the role of trait empathy on the propensity for selecting *unique* ideas. The results from the fourth hierarchical regression model showed that the design context and problem, and the course instructor, significantly predicted participants' propensity for selecting *unique* ideas, $R^2 = 0.179$, $F(4,89) = 4.62$, $p < 0.01$, which is considered a small effect. However, the design context and problem, as well as the course instructor did not significantly contribute to the model, $p > 0.05$. The addition of trait empathy (fantasy, perspective-taking, personal distress, and empathic concern) to this model also led to a statistically significant model $F(8,89) = 2.82$, $p < 0.01$, with an R^2 change of 0.039; however, all of the four empathic tendencies, fantasy, perspective-taking, personal distress, and empathic concern, did not significantly contribute to the model, $p > 0.05$.

The findings partially support our hypotheses that trait empathy predicted creative concept selection. Specifically, perspective-taking tendencies positively predicted participants' propensity for selecting elegant ideas. These results confirm previous work that highlighted the significance of perspective-taking tendencies in an engineering context (Surma-aho *et al.*, 2018*b*; Alzayed *et al.*, 2021). However, perspective-taking tendencies were only impactful for selecting elegant ideas, and not ideas rated high in overall creativity, usefulness, and uniqueness. Additionally, the other empathic tendencies, fantasy, empathic concern, and personal distress, had no significant impact on creative concept selection.

Discussion

The main goal of this paper was to explore the role of trait empathy on creative concept generation and selection. The main findings from the study are as follows:

- Empathic concern tendencies positively impacted the generation of more ideas, while personal distress tendencies negatively impacted the generation of more ideas.
- Perspective-taking tendencies positively impacted participants' propensity for selecting elegant ideas.

The implications of these findings are discussed below with respect to our research hypotheses.

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The role of empathy in concept generation

The first finding from this study indicated that while empathy impacted the number of ideas generated by participants, it did not necessarily impact the creativity of those ideas. Specifically, empathic concern tendencies positively predicted the generation of more ideas. This finding partially corroborates a qualitative investigation with engineering students (Fila and Hess, 2016) that found that empathic concern tendencies motivated students to work harder on an engineering task. Meanwhile, personal distress tendencies negatively predicted the generation of more ideas. This relates to findings in the literature that note how being empathic may restrict the designer from coming up with creative innovations to the existing problem (Mattelmäki *et al.*, 2014). While trait empathy had both a positive and negative impact on the number of ideas generated, the results found that empathy did not impact the creativity (overall creativity, usefulness, uniqueness, and elegance) of those ideas. These results resonate with the discussion in the literature that display varying points of views on the role of empathy in concept generation (Genco *et al.*, 2011; Johnson *et al.*, 2014; Breithaupt, 2019).

The role of empathy in concept selection

While the results from concept generation indicated that trait empathy did not impact the creativity of the ideas, the findings from concept selection indicated that trait empathy did impact the propensity for selecting elegant ideas. Specifically, perspective-taking tendencies positively predicted participants' propensity for selecting elegant ideas. These results underline previous work that highlights the importance of perspective-taking tendencies in engineering contexts (Surma-aho *et al.*, 2018*b*; Alzayed *et al.*, 2021). However, those results were only true for selecting elegant ideas, and not ideas rated high in overall creativity, usefulness, and uniqueness. Overall, the results from this study confirmed prior work that discussed varying points of views (Genco *et al.*, 2011; Johnson *et al.*, 2014; Breithaupt, 2019) on the role of empathy in design, whereby we find evidence that supports the notion of the utility of empathy and the negative impact of empathy in both the concept generation and selection stages of the design process. Since the design community has been invested in devising empathy invoking interventions (Raviselvam *et al.*, 2016, 2017), the results from this research call for the need to prepare *specific* interventions that trigger certain types of empathic tendencies (e.g., perspective-taking, fantasy, empathic concern, or personal distress) depending on the design stage (e.g., concept generation, concept selection) and the desired outcome (e.g., useful, unique, or elegant ideas).

Implications for AI in design

The main findings from this paper highlight that while empathy may be useful throughout design, the utility of specific types of empathy vary depending upon the design stage. The findings from this research can help guide the development of AI assistants that support designers during concept generation and selection. In this fuzzy front-end of the design process, designers are involved in numerous decisions that require cognitive effort (Toh and Miller, 2019). For example, designers would have to decide whether an idea should be selected or not during concept selection based on a specific set of criteria. Thus, in the pursuit of building better AI systems, we also need to advance a fundamental understanding of empathy.

Conclusion, limitations, and future work

The main goal of this paper was to explore the role of trait empathy on concept generation and selection in an engineering design student project. The main findings from this research highlighted that empathic concern tendencies positively impacted the generation of more ideas while personal distress tendencies negatively impacted the generation of more ideas. During concept selection, perspective-taking tendencies positively impacted participants' propensity for selecting elegant ideas. These results highlight that while empathy may be useful throughout design, the utility of specific types of empathy vary depending upon the design stage. In other words, the design community should be invested in preparing specific interventions to trigger specific types of empathic tendencies (e.g., perspective-taking, fantasy, empathic concern, or personal distress) depending on the design stage (e.g., concept generation, concept selection) and the desired outcome (e.g., useful, unique, or elegant ideas).

Despite the insights we found on the role of empathy during concept generation and selection, there are several limitations that need to be identified that could lead to interesting avenues for future research. While this work started exploring the relationship between trait empathy and creative concept generation and selection, future research should assess the relationship of trait empathy with other design outcomes, such as the quality of the final design. Moreover, while this research explored the utility of empathy in humanitarian engineering problems, future research is needed to extend these results with other engineering design tasks. Additionally, while this study investigated the role of empathy on creativity in an engineering design task, prior research has argued that the basis of empathic thinking is genetic and could impact the type of professions that individuals choose. Thus, future research is warranted to determine whether empathy has a role on the type of engineering professions they select. Finally, while prior research found that the ideation patterns of first year and senior-level students differ (Alsager Alzayed *et al.*, 2019), this work only studied first-year students. Thus, future research is warranted to extend those findings beyond first-year students. Taken as a whole, this research took the first step in encouraging empirical investigations aimed at understanding the role of trait empathy across different stages of the design process.

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Conflict of interest. The authors declare that they have no conflict of interests.

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Appendix

A sample of the data used in these analyses is presented in Tables A1–A4 in the Appendix.

Table A1. Interrater reliability (α values) between raters for idea creativity assessment

Rater	Overall Creativity	Usefulness	Uniqueness	Elegance	Drawing Abilities
Expert 1 and Expert 2	0.763	0.794	0.812	0.768	0.817
Expert 1 and Quasi-Expert 1	0.756	0.788	0.821	0.780	0.831
Expert 1 and Quasi-Expert 2	0.751	0.753	0.757	0.756	0.793
Expert 2 and Quasi-Expert 1	0.761	0.756	0.816	0.766	0.807
Expert 2 and Quasi-Expert 2	0.753	0.713	0.778	0.758	0.812
Quasi-Expert 1 and Quasi-Expert 2	0.750	0.763	0.823	0.767	0.753

Table A2. A sample of the data analyzed in RQ1

	Trait Empathy				
Participant	Perspective-Taking	Fantasy	Empathic Concern	Personal Distress	Number of ideas
1	10	7	14	5	7
2	14	20	17	8	6
3	19	13	20	15	4

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Table A3. A sample of the data analyzed in RQ2

	Trait Empathy				Creativity of generated ideas			
Participant	Perspective-Taking	Fantasy	Empathic Concern	Personal Distress	Overall	Useful	Unique	Elegant
1	10	7	14	10	2	2.93	1.71	3
2	14	20	17	14	3.08	3.58	2.50	3.25
3	19	13	20	19	2.75	2.5	3.38	3.13

Table A4. A sample of the data analyzed in RQ3

	Trait Empathy				Propensity for selecting creative ideas			
Participant	Perspective-Taking	Fantasy	Empathic Concern	Personal Distress	Overall	Useful	Unique	Elegant
1	10	7	14	10	1.00	1.02	0.96	1.04
2	14	20	17	14	1.16	1.05	1.08	1.05
3	19	13	20	19	1.24	0.99	1.32	1.14

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