ASEE 2022 ANNUAL CONFERENCE
Excellence Through Diversity
MINNEAPOLIS, MINNESOTA, JUNE 26TH-29TH, 2022 ASEE

Paper ID #36825

Expansive Empathy: Defining and Measuring a New Construct in Engineering Design

Ardeshir Raihanian Mashhadi

Vanessa Svihla

Dr. Vanessa Svihla is an associate professor at the University of New Mexico (UNM) with appointments in learning sciences and engineering. Her research, funded by an NSF CAREER award, focuses on how people learn as they frame problems and how these activities relate to identity, agency and creativity.

Expansive Empathy: Defining and Measuring a New Construct in Engineering Design

Abstract

Empathy is vital to ethical, effective design, yet vexing to teach. While research suggests empathy can be developed through human-centered design, students still tend to narrowly scope design problems, ignore the heterogeneity of the stakeholders, and focus on only mainstream or very few individuals with specific need. While engineering education has come to value empathy, literature suggests that we still have a very limited understanding of its nuances. We address this issue by introducing the construct expansive empathy, which we define as the ability to understand and generate inclusive design solutions that incorporate the complex interactions among the engineering system and the needs of diverse stakeholders, including those who are marginalized, mainstreamed, and vulnerable. We adapted the Interpersonal Reactivity Index to develop a measure to capture expansive empathy and performed an exploratory factor analysis. We examined factor structure using data collected at the beginning of a senior design class. Initial results suggest that students have not developed expansive empathy in their previous engineering courses.

Introduction and research purpose

While empathy is critical in ethical and effective design, teaching it is challenging. Research suggests empathy can be developed through human-centered design [1], as students engage with sociotechnical issues and focus on actual stakeholder needs, and especially, by focusing their attention on marginalized communities [2, 3]. Moreover, students' engagement with sociotechnical issues during engineering design has shown to improve their success in realizing actual stakeholder needs, to expand their inquiry process beyond the initial problem framing and to focus their attention toward marginalized communities [2]. Incorporating sociotechnical aspects in teaching engineering design can focus students' attention toward stakeholders' needs and capabilities, helping them propose design solutions that show empathy [2, 4].Yet, students still tend to narrowly scope design problems, ignore the heterogeneity of the stakeholders, and focus on only mainstream or very few individuals with specific needs [5]. While engineering education has come to value empathy, literature suggests our understanding of it is still limited [1].

When dealing with sociotechnical problems, typical design methods tend to fall short, leading to overly narrow and even inaccurate problem definitions [6]. Human-centered design methods, which emphasize empathic, inclusive design solutions for diverse stakeholders, are critical in design because they illuminate what stakeholders want and why [7], centering varied stakeholder needs and commonly engaging stakeholders in the design process [8, 9]. However, engaging heterogeneous stakeholders is complex work that presents a significant barrier to supporting students in learning human-centered design, especially in high-enrollment courses [9, 10]. We address this issue by introducing the construct *expansive empathy*, which we define as the ability to understand and generate inclusive design solutions that incorporate the complex interactions among the engineering system and the needs of diverse stakeholders, including those who are marginalized, mainstreamed, and vulnerable. In this study, we first sought to define subconstructs that expansive empathy comprises via literature review. We developed a survey to measure these subconstructs and used factor analysis to examine the structure.

Expansive empathy and design for sustainability

The importance of stakeholder heterogeneity, and therefore, expansive empathy is fundamental in design of sustainable systems, where there is consistent attention to sociotechnical systems. Past research suggests that designing environmentally-friendly products and systems without consideration of the heterogeneity in stakeholders' actual behaviors can be drastically inaccurate [11-14]. For example, the design decision to produce a lighter vehicle may not be environmentally trivial when considering the usage stage of the vehicle life cycle [14]. In a traditional design classroom setting, when a typical design problem is discussed, every aspect of designing a component—say a wheel—is visual and relatable to students, but as the system becomes complex, particularly when sociotechnical aspects are included (e.g., food-water-energy systems, electric power grid, etc.), the nuances that can significantly affect the design are not included in students' learning experience, resulting in less authentic problems. The vignette below illustrates an example.

Vignette 1
As part of instruction on needs analysis, problem identification and engineering requirements, Dr. Gomez asks students to do some research and be ready to discuss a prompt: "Consider a vehicle redesign strategy where the hood is made from a high strength aluminum alloy instead of steel. Argue whether or not this is a good design strategy from a sustainability viewpoint." After a chance to discuss their ideas with peers, when Dr. Gomez asks students to share, many hands go up. Eden offers a popular idea, "Obviously this is a great idea…all else aside, like cost, strength etc., this is great from a sustainability standpoint, because obviously aluminum is lighter, and this replacement provides weight savings which means a better fuel economy. Better fuel economy means less emissions and therefore more sustainability, right?" While many students shake their heads in agreement, Alexis raises a complication, "I agree, but I think it's more complicated. I found that manufacturing aluminum can use more energy and cost compared to steel, which is a negative from a sustainability standpoint. Therefore, we have to make sure the weight savings are large enough to compensate for that. We learned that it's important to make an effort to understand the stakeholder needs. I think we need to consider how long a driver drives this car and how weight savings can be translated to fuel economy. I looked at some numbers like the average expected mileage on a car and average MPG for cars. With some rounding, I think it is a good idea." Hearing no additional ideas, Dr. Gomez asks student to write their arguments in a minute paper, making sure to discuss stakeholders. On reading these, Dr. Gomez notes that stakeholders are considered in aggregate, as average and uniform.

In the vignette above, factors like driving habits, family size, urban/rural setting, and driver age, on which fuel economy depends, are missing. These stakeholder-specific factors vary and can lead to significant disparities in the benefits of such a strategy. The extra cost impacts who can afford the vehicle, and it might not even be as sustainable when stakeholder-specific factors are considered.

The literature depicts growing yet still limited understanding of the role of empathy in engineering education [1, 15, 16]. This literature suggests empathy can be developed through human-centered design thinking [1], and empathic design is characterized as the most comprehensive form of human-centered design [9]. While interactions with stakeholders are critical in developing empathy, students still tend to narrowly scope design problems, ignore the heterogeneity of the stakeholders, and focus on only mainstream or very few individuals with specific needs [9].

Measuring empathy: A situative approach

Various instruments have been developed and utilized to assess empathy. As such, we considered varied definitions of empathy and characterizations of it as cognitive and/or affective. We also wanted to contextualize our measure of expansive empathy to design, much as measures of self-efficacy are commonly contextualized to mathematics, science inquiry, engineering, etc. [17-19]. Adopting this situative approach is common when we expect affective and dispositional stances to develop in tandem with cognitive aspects and disciplinary practices, as is the case with empathy in design [20].

Thus, research on how others have measured empathy in design provides key guidance in our review of existing decontextualized or general-purpose measures. For instance, in research on design thinking, feedback-seeking has been considered a proxy for empathy [21, 22]. In such surveys, questions focus on considering alternate perspectives (e.g., “seek input from those with a different perspective from me.”), thus relating empathy to design thinking. This approach is helpful situating empathy as coupled to practices in design.

Modern general-purpose measures of empathy commonly include both affective and cognitive subconstructs. One such example is the Empathy Components Questionnaire (ECQ) [23], which measures five subconstructs of empathy: Affective ability is the capacity to share others’ emotions; affective drive is the tendency to do so; affective reactivity is the tendency to do so reactively and complementarily; cognitive ability is the capacity to consider a situation from some else’s perspective; and cognitive drive is the tendency to do so. Another general-purpose measure is the Empathy Quotient (EQ) [24-26] which measures three constructs—cognitive empathy, emotional reactivity, and social skills; attention to social skills (e.g., “I don’t tend to find social situations confusing”) in the EQ stems from the use of this measure in studying Autism. In considering expansive empathy, we recognized that the affective components—as measured by the ECQ and the EQ—could be difficult to situate within design and across marginalized, mainstreamed, and vulnerable stakeholders, at least compared to the cognitive components. This is in part because the affective items are typically written as universal emotional statements without context (e.g., “The people I am with have a strong influence on my mood”), whereas the cognitive items typically relate to regulation of a behavior or practice (e.g., “I can usually appreciate the other person's viewpoint, even if I do not agree with it.”).

Another general purpose instrument is the Interpersonal Reactivity Index (IRI) which measures four dimensions: fantasy is the tendency to place oneself into stories; perspective taking is the ability to consider situations from others’ perspectives; empathic concern is the tendency to respond to others experiencing harm with concern; and personal distress is the tendency to feel anxiety in response to others experiencing harm [5, 27]. The IRI was appealing first because it has previously been used in engineering education. For instance, in a study comparing engineering students to psychology and social sciences students, the former had significantly lower fantasy and perspective-taking scores [16]. These lower scores on perspective taking in particular are concerning, given the importance of this skill in designing [28]. Indeed, in related research using the IRI, perspective-taking was associated with innovation [29].

It is challenging to relate the IRI subscales of fantasy (e.g., “I really get involved with the feelings of the characters in a novel”) and personal distress (e.g., “I tend to lose control during emergencies”) to expansive empathy. Some empathic concern items (e.g., “When I see someone being taken advantage of, I feel kind of protective toward them”) seem highly relevant to expansive empathy, especially given our desire to consider marginalized and vulnerable stakeholders. Other empathic concern items suggest a universal rather than situative stance (e.g., “I would describe myself as a pretty soft-hearted person”), and were therefore not a focus for our study. It is comparatively straightforward to contextualize perspective-taking items on the IRI (e.g., “I try to look at everybody’s side of a disagreement before I make a decision”), and these items are similar to cognitive empathy on the ECQ and cognitive ability in the EQ.

Methodology

Based on our review of existing measures of empathy, we selected two subscales of the IRI to adapt: perspective taking and empathic concern. We first contextualized the items by bringing them into a design context. Next, we expanded the questions to focus on individual stakeholders, vulnerable stakeholders, and multiple stakeholders. As a result, the single question, “I try to look at everybody’s side of a disagreement before I make a decision” became three questions:

- I try to look at a specific stakeholder’s point of view before I make a decision.
- I try to look at multiple, different stakeholder’s point of view before I make a decision.
- I try to look at a vulnerable stakeholder’s point of view before I make a decision.

Finally, we expanded the scales to 7 points, based on research suggesting this scale may be more sensitive [30]. We anticipated six factors, grouped by empathic concern and perspective taking, as well as stakeholder form (single, multiple, vulnerable).

We collected data at the beginning of the Fall 2021 semester (under an existing approved IRB) from the Design Process and Methods class, which is a required class for senior students and is the first class in a capstone design sequence (N = 176).

The Kaiser-Meyer-Olkin (KMO) measure indicated that our sample was suitable for factor analysis, KMO = .85, well above the cutoff of .6 [31]. Bartlett’s test of sphericity was significant (χ^2 (435) = 2516.37, $p < .001$), also indicating that factor analysis was appropriate. Because our data were not normally distributed, as expected with Likert scaled data, and were intercorrelated, as is common with social constructs, we used exploratory factory analysis, with principal axis factoring and a promax rotation [32-34]. We retained items provided they had loadings of at least 0.40 and were not cross-loaded [35, 36]. We reviewed factors for internal consistency, retaining factors with at least three items and with a Cronbach’s alpha of at least .7.

We also calculated descriptive statistics for items and for resultant factors. We conducted ANOVAs to make comparisons between factors.

Results and discussion

In contrast to our expectations, we did not extract six factors tied to stakeholder type. This may suggest that the students did not differentiate between stakeholder types or that our items were not able to identify differences present. This indicates further development may be conducted if we prefer to maintain a focus on discrete stakeholder types. In the present study, we instead proceed with interpretation of the factors extracted.

We identified five factors (Table 1), three related to perspective taking (framing; tentativeness; ability) and two related to empathic concern (empathic concern, protectiveness).

Table 1. Final set of retained questions by factor

	1	2	3	4	5	M (SD)	α if item deleted
Factor: Empathic concern (α = 0.86), reverse scored items.							
Sometimes I don't feel very sorry for multiple different stakeholders when I'm working on a design problem	0.40	0.03	0.14	-0.09	-0.06	4.56 (1.17)	0.86
Multiple different stakeholder's misfortunes related to a design problem do not usually disturb me a great deal	0.87	0.09	-0.01	-0.06	-0.05	4.99 (1.3)	0.84
When I see that multiple different stakeholders are impacted unfairly by a problem, I sometimes don't feel very much pity for them	0.48	0.00	0.00	0.00	-0.04	5.2 (1.17)	0.84
A specific stakeholder's misfortunes related to a design problem do not usually disturb me a great deal	0.78	-0.08	0.02	0.08	0.06	4.77 (1.32)	0.84
When I see that a specific stakeholder is impacted unfairly by a problem, I sometimes don't feel very much pity for them	0.55	-0.16	0.10	0.09	-0.02	5.03 (1.19)	0.84
A vulnerable stakeholder's misfortunes related to a design problem do not usually disturb me a great deal	0.93	0.06	-0.14	-0.08	0.03	4.89 (1.21)	0.84
When I see that a vulnerable stakeholder is impacted unfairly by a problem, I sometimes don't feel very much pity for them	0.51	-0.02	0.03	-0.02	0.09	5.00 (1.34)	0.84
Factor: Perspective taking as framing (α = 0.85)							

I try to look at multiple, different stakeholder's point of view before I make a decision.	0.22	0.50	0.10	0.06	0.01	5.83 (1.03)	0.83
I sometimes try to understand design problems better by imagining how things look from multiple different stakeholder's perspective	0.16	0.62	-0.02	0.05	-0.03	5.78 (0.95)	0.82
I believe that understanding multiple different points of view is necessary for solving a design problem	0.11	0.58	0.11	0.06	-0.08	6.19 (1.09)	0.85
I try to look at a specific stakeholder's point of view before I make a decision.	-0.15	0.67	0.03	-0.06	0.01	5.43 (1.06)	0.83
I sometimes try to understand design problems better by imagining how things look from a specific stakeholder's perspective	0.02	0.80	-0.08	-0.19	0.08	5.59 (0.98)	0.81
I try to look at a vulnerable stakeholder's point of view before I make a decision.	-0.09	0.56	0.01	0.17	-0.06	5.39 (1.15)	0.84
I sometimes try to understand design problems better by imagining how things look from a vulnerable stakeholder's perspective	-0.03	0.54	0.04	0.08	0.11	5.44 (1.03)	0.82
Factor: Perspective taking tentativeness (α = 0.89), reverse scored items							
If I'm sure a design decision is right, I don't waste much time seeking multiple different stakeholder's point of view	-0.03	0.05	0.99	0.00	0.03	4.79 (1.45)	0.81
If I'm sure a design decision is right, I don't waste much time seeking a stakeholder's point of view	0.05	0.02	0.81	-0.01	-0.03	4.59 (1.57)	0.85
If I'm sure a design decision is right, I don't waste much time seeking a vulnerable stakeholder's point of view	-0.06	-0.02	0.78	-0.01	0.05	4.65 (1.44)	0.86
Factor: Protectiveness (α = 0.85)							
When I see that multiple different stakeholders are being taken advantage of by existing design solutions, I feel kind of protective towards them.	-0.09	0.15	-0.03	0.81	-0.10	4.92 (1.1)	0.78

When I see that a specific stakeholder is being taken advantage of by existing design solutions, I feel kind of protective towards them.	-0.11	-0.05	-0.02	0.85	0.07	4.89 (1.05)	0.81
When I see that a vulnerable stakeholder is being taken advantage of by existing design solutions, I feel kind of protective towards them.	0.18	-0.02	0.04	0.77	0.02	4.94 (1.16)	0.76
Factor: Perspective taking ability (α = 0.77), reverse scored items							
I sometimes find it difficult to see a problem from multiple, different stakeholders' points of view.	-0.03	0.14	0.00	-0.03	0.85	4.43 (1.46)	0.63
I sometimes find it difficult to see a problem from a specific stakeholder's point of view.	0.01	-0.07	0.06	0.01	0.74	4.35 (1.41)	0.72
I sometimes find it difficult to see a problem from a vulnerable stakeholder's point of view.	0.08	-0.05	-0.02	0.03	0.64	4.47 (1.31)	0.73

Students generally agreed that they considered stakeholder needs when making decisions about the problem, yet they also acknowledged the difficulty of doing so, especially when they felt fairly confident about a particular decision, reflected by the significantly lower values for these factors (Figure 1).

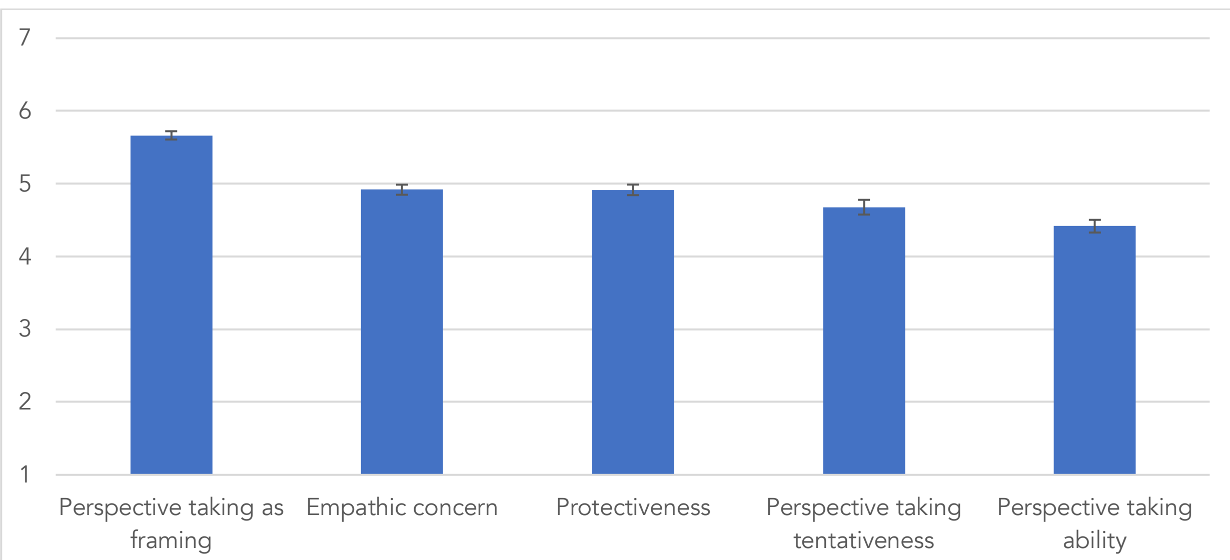

Figure 1. Students' mean scores on expansive empathy subconstructs. Error bars are standard errors.

As both empathic concern and perspective taking as framing included at least two items for each stakeholder type, we also created variables and compared their means. Students did not differentiate between stakeholder types with regard to empathic concern (multiple stakeholders $M = 4.92$, $SD = 0.96$; specific stakeholders $M = 4.90$, $SD = 1.06$; vulnerable stakeholders $M = 4.94$, $SD = 1.10$). However, we found the students significantly more strongly agreed that they framed problems in light of multiple stakeholders ($M = 5.94$, $SD = 0.80$) than either specific ($M = 5.51$, $SD = 0.92$, $F[1,174]=58.23$, $p < .001$, $\eta^2 = .25$) or vulnerable stakeholders ($M = 5.42$, $SD = 0.91$ $F[1,174]=80.20$, $p < .001$, , $\eta^2 = .32$). This may indicate that students recognized the importance of defining problems from multiple points of view, but that this comes at a cost to attending to vulnerable stakeholders.

Conclusions, implications and limitations

While literature suggests that empathy in engineering design can be developed via human-centered design [1], students still tend to narrowly scope design problems and corresponding requirements with respect to stakeholder personas based on averages in the population or users with very specific needs [5]. This can lead to limited or even inappropriate design solutions particularly in problems involving sociotechnical systems [6].

In this study we defined the construct expansive empathy as the ability to understand and generate inclusive design solutions that incorporate the complex interactions among the engineering system and the needs of diverse stakeholders, including those who are marginalized, mainstreamed, and vulnerable. We adapted the IRI [5, 27], a four-factor measure of empathy, by bringing two of these factors into the design context, expanding the questions to focus on heterogenous stakeholders and adjusting the scales to 7 points. Applying exploratory factor analysis, we identified five factors related to perspective taking and empathic concern. The difference between the factor structure in the adapted measure and the original IRI suggests that both empathic concern and perspective taking, when situated in design contexts with varied stakeholders, are more nuanced that when considered as universals. This is similar to results found with contextualized measures of other general constructs, suggesting that bringing constructs into specific contexts, where practices intersect with dispositions and cognitive development, also means taking a more nuanced approach.

Our results suggest that empathic concern and perspective taking, rather than disaggregating by stakeholder type, intersect with other design practices and dispositions. Specifically, perspective taking, contextualized to design, intersects with making consequential decisions about framing the problem and staying tentative, and these as separable from the more cognitive capacity to simply take varying perspectives. Our results thus illustrate a more expansive view of empathy in design than has been previously measured. The main implication of this would be that other researchers can use the survey and investigate this construct further, particularly in other contexts.

In analysis of subscales, we found that students seemed to value multiple stakeholders over specific and vulnerable stakeholders. While we agree that considering heterogenous perspectives if valuable, we wonder how often this effort settles on a mean, rather than truly considering variability. In particular, we think there is important work to be done to understand problems from varied and marginalized points of view, and especially, to understand how to teach students to take such perspectives meaningfully into their design problem framing. Notably, recent research suggests that students espouse that they value diverse perspectives, yet their actions in capstone design run counter to these values [37]. This is a clear equity issue, and future studies can focus on techniques drawn from justice, equity, diversity, and inclusivity (JEDI) research to better support the development of engineers who both value and act on these values.

One limitation of this work is that this study was done only one time, in one university and one class. Therefore, in our on-going and future work we will focus on expanding the data collection to other universities, majors other than Mechanical and Aerospace Engineering and first year students. By doing so, we would be able to further investigate developmental trajectories as well as disciplinary differences in light of typical and design-focused engineering curricula.

Many open questions remain about developmental trajectories in particular. We do not know how expansive empathy is developed over time or if students would be able to transfer it after developing it. Another question to answer in future work is what kind of, if any, intervention would help students develop expansive empathy. The measure developed in this study will help us and other researchers to investigate this further.

Acknowledgments

This material is based upon work supported by the National Science Foundation under Grant No. EEC 1751369. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

References

[1] J. L. Hess and N. D. Fila, "The development and growth of empathy among engineering students," *Proceedings of the American Society for Engineering Education Annual Conference & Exposition,* 2016, doi: 10.18260/p.26120.

[2] D. A. Chen, M. A. Chapman, and J. A. Mejia, "Balancing complex social and technical aspects of design: Exposing engineering students to homelessness issues," *Sustainability,* vol. 12, no. 15, p. 5917, 2020, doi: 10.3390/su12155917.

[3] R. Olson *et al.*, "Developing changemaking engineers–Year four," *Proceedings of the American Society for Engineering Education Annual Conference & Exposition,* 2019, doi: 10.18260/1-2--32203.

[4] S. M. Lord *et al.*, "Creative Curricula for Changemaking Engineers," *Proccedings of the World Engineering Education Forum-Global Engineering Deans Council,* pp. 1-5, 2018.

[5] M. H. Davis, "Measuring individual differences in empathy: Evidence for a multidimensional approach," *Journal of personality and social psychology,* vol. 44, no. 1, p. 113, 1983, doi: 10.1037/0022-3514.44.1.113.

[6] B. Wilkerson and L.-K. L. Trellevik, "Sustainability-oriented innovation: Improving problem definition through combined design thinking and systems mapping approaches," *Thinking Skills and Creativity,* vol. 42, p. 100932, 2021, doi: 10.1016/j.tsc.2021.100932.

[7] F. Ceschin and I. Gaziulusoy, "Evolution of design for sustainability: From product design to design for system innovations and transitions," *Design studies,* vol. 47, pp. 118-163, 2016, doi: 10.1016/j.destud.2016.09.002.

[8] T. Zhang and H. Dong, "Human-centred design: An emergent conceptual model," *Include2009 proceedings,* 2009. [Online]. Available: https://bura.brunel.ac.uk/bitstream/2438/3472/1/Fulltext.pdf.
[9] C. B. Zoltowski, W. C. Oakes, and M. E. Cardella, "Students' ways of experiencing human-centered design," *Journal of Engineering Education,* vol. 101, no. 1, pp. 28-59, 2012, doi: 10.1002/j.2168-9830.2012.tb00040.x.
[10] J. B. Scott, "The practice of usability: Teaching user engagement through service-learning," *Technical Communication Quarterly,* vol. 17, no. 4, pp. 381-412, 2008, doi: 10.1080/10572250802324929.
[11] A. Raihanian Mashhadi and S. Behdad, "Discriminant effects of consumer electronics use-phase attributes on household energy prediction," *Energy policy,* vol. 118, pp. 346-355, 2018, doi: 10.1016/j.enpol.2018.03.059.
[12] A. Sekar, E. Williams, and R. Chen, "Changes in time use and their effect on energy consumption in the United States," *Joule,* vol. 2, no. 3, pp. 521-536, 2018, doi: 10.1016/j.joule.2018.01.003.
[13] A. Sekar, E. Williams, and R. Chen, "Heterogeneity in time and energy use of watching television," *Energy Policy,* vol. 93, pp. 50-58, 2016, doi: 10.1016/j.enpol.2016.02.035.
[14] C. Telenko and C. C. Seepersad, "Probabilistic graphical modeling of use stage energy consumption: a lightweight vehicle example," *Journal of Mechanical Design,* vol. 136, no. 10, p. 101403, 2014, doi: 10.1115/1.4027983.
[15] J. Strobel, J. L. Hess, R. Pan, and C. A. Wachter Morris, "Empathy and care within engineering: Qualitative perspectives from engineering faculty and practicing engineers," *Engineering Studies,* vol. 5, no. 2, pp. 137-159, 2013.
[16] C. Rasoal, H. Danielsson, and T. Jungert, "Empathy among students in engineering programmes," *European Journal of Engineering Education,* vol. 37, no. 5, pp. 427-435, 2012, doi: 10.1080/03043797.2012.708720.
[17] F. Pajares, "Self-efficacy beliefs in academic settings," *RED,* vol. 66, no. 4, pp. 543-578, 1996, doi: 10.3102/00346543066004543.
[18] N. A. Mamaril, E. L. Usher, C. R. Li, D. R. Economy, and M. S. Kennedy, "Measuring undergraduate students' engineering self-efficacy: A validation study," *Journal of Engineering Education,* vol. 105, no. 2, pp. 366-395, 2016, doi: 10.1002/jee.20121.
[19] P. L. Brown, J. P. Concannon, D. Marx, C. Donaldson, and A. Black, "An examination of middle school students' STEM self-efficacy, interests and perceptions," *Journal of STEM Education: Innovations and Research,* vol. 17, no. 3, 2016. [Online]. Available: https://www.jstem.org/jstem/index.php/JSTEM/article/view/2137/1784.
[20] J. Walther, S. E. Miller, and N. W. Sochacka, "A model of empathy in engineering as a core skill, practice orientation, and professional way of being," *Journal of Engineering Education,* vol. 106, no. 1, pp. 123-148, 2017, doi: 10.1002/jee.20159.
[21] E. Coleman, T. Shealy, J. Grohs, and A. Godwin, "Design thinking among first-year and senior engineering students: A cross-sectional, national study measuring perceived ability," *Journal of Engineering Education,* vol. 109, no. 1, pp. 72-87, 2020.
[22] J. Blizzard, L. Klotz, G. Potvin, Z. Hazari, J. Cribbs, and A. Godwin, "Using survey questions to identify and learn more about those who exhibit design thinking traits," *Design Studies,* vol. 38, pp. 92-110, 2015, doi: 10.1016/j.destud.2015.02.002.

[23] L. Batchelder, M. Brosnan, and C. Ashwin, "The development and validation of the empathy components questionnaire (ECQ)," *PloS one,* vol. 12, no. 1, p. e0169185, 2017, doi: 10.1371/journal.pone.0169185.
[24] C. Allison, S. Baron-Cohen, S. Wheelwright, M. H. Stone, and S. J. Muncer, "Psychometric analysis of the Empathy Quotient (EQ)," *Personality and Individual Differences,* vol. 51, no. 7, pp. 829-835, 2011, doi: 10.1016/j.paid.2011.07.005
[25] S. Baron-Cohen and S. Wheelwright, "The empathy quotient: An investigation of adults with Asperger syndrome or high functioning autism, and normal sex differences," *Journal of Autism and Developmental Disorders,* vol. 34, no. 2, pp. 163-175, 2004, doi: 10.1023/B:JADD.0000022607.19833.00.
[26] E. J. Lawrence, P. Shaw, D. Baker, S. Baron-Cohen, and A. S. David, "Measuring empathy: Reliability and validity of the empathy quotient," *Psychological Medicine,* vol. 34, no. 5, pp. 911-920, 2004, doi: 10.1017/S0033291703001624.
[27] M. H. Davis, "A multidimensional approach to individual differences in empathy," *JSAS Catalog of Selected Documents in Psychology,* vol. 10, no. 85, 1980.
[28] J. L. Hess, J. Strobel, and A. O. Brightman, "The development of empathic perspective-taking in an engineering ethics course," *Journal of Engineering Education,* vol. 106, no. 4, pp. 534-563, 2017, doi: 10.1002/jee.20175.
[29] J. L. Hess, N. D. Fila, and S. Purzer, "The relationship between empathic and innovative tendencies among engineering students," *The International journal of engineering education,* vol. 32, no. 3, pp. 1236-1249, 2016.
[30] D. A. Dillman, J. D. Smyth, and L. M. Christian, *Internet, phone, mail and mixed-mode surveys: The tailored design method*. Hoboken, NJ: Wiley, 2016.
[31] C. D. Dziuban and E. C. Shirkey, "When is a correlation matrix appropriate for factor analysis? Some decision rules," *Psychological Bulletin,* vol. 81, no. 6, p. 358, 1974, doi: 10.1037/h0036316.
[32] J. C. de Winter and D. Dodou, "Factor recovery by principal axis factoring and maximum likelihood factor analysis as a function of factor pattern and sample size," *Journal of Applied Statistics,* vol. 39, no. 4, pp. 695-710, 2012, doi: 10.1080/02664763.2011.610445.
[33] L. R. Fabrigar, D. T. Wegener, R. C. MacCallum, and E. J. Strahan, "Evaluating the use of exploratory factor analysis in psychological research," *Psychological methods,* vol. 4, no. 3, p. 272, 1999, doi: 10.1037/1082-989X.4.3.272
[34] J. W. Osborne, "What is rotating in exploratory factor analysis?," *Practical Assessment, Research, and Evaluation,* vol. 20, no. 1, p. 2, 2015, doi: 10.7275/hb2g-m060.
[35] J. W. Osborne, A. B. Costello, and J. T. Kellow, "Best practices in exploratory factor analysis," *Practical Assessment, Research, and Evaluation,* vol. 10, no. 7, pp. 1-9, 2008, doi: 10.7275/hb2g-m060
[36] M. Tavakol and R. Dennick, "Making sense of Cronbach's alpha," *International Journal of Medical Education,* vol. 2, p. 53, 2011, doi: 10.5116/ijme.4dfb.8dfd.
[37] G. Guanes, L. Wang, D. A. Delaine, and E. Dringenberg, "Empathic approaches in engineering capstone design projects: student beliefs and reported behaviour," *European Journal of Engineering Education,* pp. 1-17, 2021, doi: 10.1080/03043797.2021.1927989.