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Practicing Engineers' Perceptions of Empathy and Care: Derived Exploratory Factor Structure from a 37-Item Survey

Justin L Hess, Purdue University, West Lafayette

Justin Hess is a Ph.D. candidate at Purdue University's School of Engineering Education and a National Science Foundation Graduate Research Fellow. He received his BS in Civil Engineering in 2011 with a minor in philosophy and hopes to receive his MSCE in December of 2014, both from Purdue University. His research focuses on understanding engineers' core values, dispositions, and worldviews. His dissertation focuses on conceptualizations, the importance of, and methods to teach empathy to engineering students. He is currently the Education Director for Engineers for a Sustainable World and an assistant editor for Engineering Studies.

Dr. Johannes Strobel, Texas A&M University

Dr. Johannes Strobel is Director, Educational Outreach Programs and Associate Professor, Engineering and Education at Texas A&M. After studying philosophy and information science at three universities in Germany, he received his M.Ed. and Ph.D. in Learning Technologies from the University of Missouri-Columbia. He worked at Concordia University, Montreal and has been the director of the Institute of P-12 Engineering Research and Learning at Purdue University. NSF and several private foundations fund his research. His research and teaching focuses on engineering as an innovation in P-12 education, policy of P-12 engineering, how to support teachers and students' academic achievements through engineering, the measurement and support of the change of 'engineering habits of mind' particularly empathy and the use of cyber-infrastructure to sensitively and resourcefully provide access to and support learning.

Dr. Rui Pan, Purdue University, West Lafayette

Dr. Pan earned her B.S. in Electrical Engineering from Hefei University of Technology and received both her M.S. in Statistics and Ph.D in Engineering Education from Purdue University.

Dr. Carrie A. Wachter Morris, Purdue University, West Lafayette

Dr. Wachter Morris is an associate professor and co-director of the School Counseling program at Purdue University. Her research interests include scholarship of teaching and learning, empathy and care, and crisis prevention and intervention.

Practicing Engineers' Perceptions of Empathy and Care: Derived Exploratory Factor Structure from a 37-Item Survey

This study continues the discussion on what skills or dispositions engineers should possess[1], specifically focusing on two attributes that seem to underlie the National Academy of Engineering's "habits of mind"[2], empathy and care. Niewoehner and Steidle (2009) suggested one of the goals of engineering education must be to instill "habits of mind and principles of action that the student can portage to the circumstances of their professional lives" (p. 9).[3] These authors suggested habits of mind may be understood as certain intellectual virtues which include (a) intellectual humility, (b) intellectual courage, (c) intellectual empathy, (d) intellectual integrity, (e) intellectual perseverance, (f) confidence in reason, (g) intellectual autonomy, (h) fair-mindedness, and (i) intellectual curiosity. They describe intellectual empathy as follows:

> *Intellectual empathy* is awareness of the need to actively entertain views that differ from our own, especially those with which we strongly disagree. It entails accurately reconstructing others' viewpoints and to self-consciously reason from premises, assumptions, and ideas other than our own.[3]

While most of Niewoehner and Steidle's intellectual virtues are closely aligned with ABET's criterion 3 student outcomes[4], this study focuses on two attributes or habits of mind that seem to be especially important, empathy and care. Within engineering literature, explicit attention to empathy and care has been minimal, as shown in a recent pilot literature review research study where just over 20 sources within engineering that explicitly use the term empathy were found, and just over 20 sources that explicitly use the term care were found.[5] Comparing the use of empathy and care in this found literature with literature outside of engineering, the authors found moderate differences in the uses of the terms as compared with each other and as compared to the broader body of knowledge in fields outside of engineering. For example, in the context of engineering, empathy was discussed as highly relevant for engineers through indirect interactions with users, whereas in helping fields literature such as nursing[6; 7] and counseling[8], empathy tends to be used in a direct person-to-person context.

This pilot literature review study was followed-up with an "extensive" literature review where the conceptualizations of empathy and care in the found articles was closely examined.[9; 10] Our research team collected terms commonly used to describe or define empathy or care in these sources, formed a list of the most common "like-terms", and followed the same literature review process with this list of terms. We found these terms to be much more prevalent in engineering literature, suggesting that empathy and care do have presence within engineering although there explicit usage has been historically minimal. The lack of explicit use of these terms in engineering literature may indicate that a concerted discourse of these constructs is missing. Yet, explicit use of these terms in recent years is growing. Take for example that "empathic design" has been considered the most "comprehensive category" of human-centered design[11; 12] or means by which empathy is already being incorporated into engineering education.[13; 14]

Beyond engineering, empathy has been declared as one of the essential ingredients for human subsistence.[15; 16] Recent studies in cognitive neuroscience, in particular the discovery of mirror neurons, have led scientists to suggest empathy is innate to nearly all of humanity[17] and that a lack of empathy, as evident via the dysfunction of the mirror neuron system, is directly related to autism[18]. In the context of engineering, research regarding how to measure the presence of empathy, to what degree empathy exists in engineering practice and implications for the education of the next generation of engineers is needed. This paper is continuing research in these areas.

Purpose and Research Questions

The purpose of this research was to deploy and test a quantitative instrument to measure working engineers' perceptions of the importance of empathy and care in their engineering practice. We used our findings from previous primarily qualitatively conducted studies to quantitatively explore practicing engineers' perceptions of empathy and care within their own work. While our previous studies have mostly explored the literature and engineering and non-engineering faculty's perceptions, this study seeks to gather the perspective of working engineers. The authors have created and tested a 37-item questionnaire consisting primarily of Likert-scale questions. Exploratory factor analysis was used to demark nuances between responses and to understand the underlying factor structure of the survey and, in turn, we explore engineers' deemed importance of empathy and care in different aspects of their work. As such, this research is guided by the following research question, "What is the underlying factor structure of the empathy and care questionnaire?" A valid and reliability tested instrument lays the groundwork for additional research and enables us to move this research and the field forward.

Conceptualizing Empathy and Care

Empathy is defined in a multiplicity of ways across many different academic disciplines.[7; 19-21] Most commonly, empathy is depicted as cognitive, affective, or both.[19; 22] Smith (1759) coined the term sympathy long ago which he referred to as fellow-feeling where there is a matching of emotional states between an observer and an actor.[23] Kohler (1929) argued that empathy is better depicted as the understanding of another's feelings rather than the matching of them.[24] Davis (1983) suggested more recently that empathy is better depicted as a multi-dimensional construct, which involves cognitive perspective taking, the ability to imagine oneself in other's positions, the tendency to have self-oriented feelings of personal distress, and the tendency to have other-oriented feelings of empathic concern.[19; 25] Each of these constructs are distinct but related, and as such individuals may be stronger in some components of empathy than others (e.g. one can excel at taking other's perspectives and not have a tendency to become empathically concerned).

Care is a similarly complex construct. For the purposes of this study, we frame care within the context of empathy, as many researchers before us have done. For example, within nursing literature, empathy has been depicted as care, where care involves concern for the outcome of an intervention.[7] Newman (2012) suggested caring builds on emotions aroused by empathy.[26] Sutherland (1993) depicted empathy as a process which starts with cognition, then affection, culminating in a behavioral response (such as care).[27] In our study, we follow this lead, depicting care ontologically with pragmatic connotations, which necessarily results in some action. We analyze these constructs of empathy and care as a unit with the premise that engineers do not simply understand, but act on their understanding and therefore engineers entering the professions need to be trained accordingly. We posit that situated together and within an engineering context, empathy is describing an affective disposition, whereas care is aimed towards making decisions and acting upon these dispositions.

Method

As a research team, we designed a survey based on previous research findings including (a) pilot literature reviews[5], (b) extensive literature reviews[9; 10], (c) small-group interviews with engineering faculty[9; 10], and (d) small-group interviews with non-engineering faculty[10]. We disseminated the survey to engineering alumni from a large Mid-Western university. In total, 1574 useful responses were received. The data collected were not normally distributed. We began data analysis using exploratory factor analysis in order to discover the primary interrelationships among survey questions and to identify factors related to the presence and importance of empathy and care in engineering practice.

Survey Design

We designed the survey in this study using themes derived from our previous studies.[5; 9; 10] In Appendix A we have included the entire 37-item survey, excluding demographic questions. We intentionally did not define empathy or care for our participants. Rather, at the end of the survey we invited participants to leave comments or participate in follow-up interviews in which they define empathy and care for us. These results are presented in an separate manuscript currently under review.[28]

We invited 20,000+ engineering alumni from a large Mid-Western university to partake in the study. From that pool, 2148 participants at least opened the survey. We removed 524 of these participants from this pool for having not completed the survey and 50 more participants for failing to answer six (6) or more questions. Therefore, we did not remove participants that neglected to answer between one (1) and five (5) questions. After removing a total of 574 participants, 1574 participants remained for exploratory factor analysis.

Survey Participants' Demographics

The demographic information we collected from participants included (a) age, (b) gender, (c) years working as an engineer, (d) years working within academia, (e) engineering degree, and (f) current engineering practice. The engineering disciplines participants could select from were depicted by the specific degree offerings from the university through which the survey was being disseminated. Table 2 shows the profession(s) of survey participants at the time of the survey. For each question participants were allowed to select multiple disciplines, so relative percentages are not relevant. Tables 1 and 2 show the gender and years of work experience of our sample, respectively.

Table 1

Gender of survey participants

Gender	Number of Participants	Relative percentage of sample
Male	1270	80.7%
Female	296	18.8%
Missing	8	0.5

Table 2

Years of work experience of survey participants

Years of work experience	Number of participants	Relative percentage of sample
0 – 1	34	2.2%
2 – 19	607	38.6%
20 – 39	665	42.2%
Above 40	226	14.4%
Missing	42	2.7%

Table 3

Engineering practice of the participants in the survey sample

Engineering Discipline	Number of participants
Astronautical or Aeronautical	150
Agricultural or Biological	25
Biomedical	45
Chemistry	145
Civil	223
Construction Engineering Management	125
Electrical or Computer	336
Engineering Education	31
Industrial	202
Interdisciplinary	42
Materials	83
Mechanical	324
Multi-Disciplinary	116
Nuclear	31
Other	161

Exploratory Factor Analysis

Factor analysis is used as a data reduction technique and for the development of scales.[29] We used exploratory factor analysis before outputting descriptive statistics in order to discover the primary interrelationships among survey questions. When performing factor analysis we excluded questions 13-16 because these questions are on a scale of 1-100 whereas all other questions varied on a Likert scale from 1-6 (see Appendix A). Questions 13-16 were separately examined and analyzed.

The 33 items from the Empathy and Care Survey set on 6-point Likert scales with endpoints of strongly disagree and strongly agree were subjected to principal component analysis using SPSS version 20. Before performing this analysis we assessed the suitability of the data for factor analysis. The correlation matrix showed multiple coefficients greater than 0.3. Our sample size was large enough, the 10:1 ratio of participants:questions criteria was well met, the Kaiser-Meyer-Olkin Measure of sampling adequacy was 0.921[30], and Barlett's Test of Spherity[31] gave a significance value of 0.000 supporting factorability of the correlation matrix.

Principal component analysis revealed the presence of eight components with eigenvalues exceeding 1, with the cumulative explanation of the total variance increasing slightly above 1% for factors 5, 6, 7, and 8 (see Table 4). An inspection of the scree plot revealed a significant break from components 1 to 2, and components 4 to 5. We therefore retained four factors for further investigation per the "elbow" rule.[32]

Table 4

Principal component analysis of the Empathy and Care Survey

	Initial Eigenvalues		
Component	Total	% of Variance	Cumulative %
1	10.095	30.590	30.590
2	2.394	7.253	37.843
3	1.967	5.962	43.805
4	1.795	5.438	49.243
5	1.292	3.914	53.157
6	1.171	3.549	56.706
7	1.123	3.403	60.109
8	1.030	3.120	63.229
9	.918	2.781	66.010

We used parallel analysis to check this initial result with the program Monte Carlo PCA for Parallel Analysis[33], (inputting 33 variables x 1574 respondents). In the following table we see the criterion values generated from the program. Comparing these to the actual eigenvalues from PCA we can ascertain the number of factors to keep by examining when the actual eigenvalue becomes less than the criterion value. Table 5 shows that 6 factors should be retained.

Table 5

Eigenvalues generated from principal component analysis

Component Number	Actual Eigenvalue from PCA	Criterion value from Monte Carlo PCA for parallel analysis	Decision
1	10.095	1.2768	Accept
2	2.394	1.2445	Accept
3	1.967	1.2201	Accept
4	1.795	1.1974	Accept
5	1.292	1.1776	Accept
6	1.171	1.1574	Accept
7	1.123	1.1412	**Reject**

Next, we used the component matrix to decide if we should keep 6 or less factors. Inputting 3, 4, 5, and 6 (in different trials) for the number of factors, SPSS produces a "Pattern Matrix" showing how strong questions load onto a given component. Starting with 6 components and examining the output, many items loaded onto the first 4 potential factors and only four and three items on the 5th and 6th factors, respectively. Twelve items loaded onto factor 2, eight items onto factors 3 and 4, three items on factor 5, and only two items on factor 6. The 4-factor solution explained 49.2% of the variance, the 5-factor solution explained 53.2%., and the 6 factor solution explained 56.7%.

The following factors represent the groupings derived from the 6-factor pattern matrix, testing for reliability. The Cronbach's Alpha for Factors 1-6 in order are as follows: F1 = 0.858, F2 = 0.859, F3 = 0.826, F4 = 0.837, F5 = 0.615, and F6 = 0.679. F5 and F6 were unreliable factor structures ($\alpha < 0.7$). Following are the factors and the associated questions (note that the numbers represent the numbered questions in Appendix A).

1. Questions 23, 24, 25, 26, 27, 28, 29, and 30
2. Questions 5, 6, 8, 10, 11, 12, and 31
3. Questions 22, 32, 33, 34, 35, 36, and 37
4. Questions 1, 2, 3, 4, and 7
5. *Questions 18, 19, and 20*
6. *Questions 9 and 17*

Given these considerations, we next output a 4-factor pattern matrix. An oblimin rotation was performed to assist the 4-component output interpretation. This output showed numerous strong loadings onto each of the four components, which added support to this structure. Table 6 shows the resulting pattern matrix, structure matrix, and communalities for each item. Only pattern coefficients with loadings greater than .3 were considered potentially retainable on a given factor, but the question was removed from the factor if it reduced its overall reliability as indicated by comparing the alpha coefficient when the item was and was not included.

Table 6

Pattern and Structure Matrix for Principal Component Analysis with Oblimin Rotation

	Pattern coefficients				Structure coefficients				
Item	F1	F2	F3	F4	F1	F2	F3	F4	Communalities
Q25	**.788**	.085	-.026	.030	.758	-.169	.299	.233	.583
Q26	**.768**	.064	-.088	.090	.735	-.179	.251	.272	.555
Q27	**.714**	.090	-.015	.098	.707	-.158	.297	.281	.514
Q28	**.710**	-.036	.054	.089	.770	-.299	.396	.320	.607
Q29	**.702**	-.206	-.101	-.192	.669	-.363	.196	.026	.519
Q24	**.644**	-.038	.063	.117	.718	-.289	.386	.332	.536
Q30	**.607**	-.328	-.040	-.263	.619	-.455	.228	-.027	.523
Q23	**.528**	.061	.167	.193	.636	-.196	.436	.384	.470
Q19	***.490***	-.082	.115	.007	.568	-.273	.350	.203	.343
Q18	***.357***	.039	.149	.045	.422	-.127	.306	.186	.200
Q20	.280	-.100	.250	-.163	.372	-.222	.347	.017	.210
Q5	-.045	**-.804**	.122	.033	.277	-.830	.331	.233	.703
Q6	-.030	**-.794**	.029	.103	.269	-.815	.262	.276	.675
Q8	-.047	**-.665**	-.015	.224	.226	-.694	.213	.350	.526
Q12	.119	**-.584**	.137	.144	.408	-.691	.390	.348	.555
Q10	.138	**-.581**	.111	.141	.413	-.686	.370	.342	.544
Q11	.282	**-.423**	.014	.216	.487	-.565	.315	.394	.466
Q31	.262	**-.390**	.252	-.056	.479	-.530	.453	.183	.436
Q35	.047	-.065	**.768**	-.014	.393	-.284	.802	.249	.649
Q33	-.048	-.267	**.739**	-.093	.328	-.431	.762	.178	.646
Q32	.020	-.067	**.730**	.036	.365	-.279	.768	.280	.597
Q37	-.101	-.008	**.653**	-.129	.144	-.124	.572	.044	.354
Q34	.125	.124	**.647**	.145	.405	-.123	.712	.353	.548
Q36	.135	-.066	**.635**	.059	.446	-.294	.729	.307	.560
Q22	.054	.126	**.407**	.311	.278	-.069	.491	.424	.338
Q17	-.012	-.025	.291	.251	.194	-.154	.369	.342	.195
Q9	.126	-.018	.261	.157	.289	-.164	.368	.278	.179
Q4	-.001	-.173	-.002	**.761**	.274	-.338	.277	.798	.665
Q3	.039	-.190	-.019	**.759**	.312	-.363	.282	.806	.688
Q1	.155	-.022	.076	**.659**	.386	-.237	.351	.732	.574
Q7	.037	-.256	-.003	**.611**	.296	-.400	.269	.677	.526
Q2	.033	-.281	-.032	**.545**	.267	-.401	.225	.605	.444
Q21	.303	.172	.169	***.333***	.417	-.044	.354	.435	.323

Derived Factor Structure

Four factors were derived from the exploratory factor analysis which were found to be internally consistent. The authors named these factors by examining the questions paired to each factor, including the question prompt and the specific questions themselves. After extensive conversation, the authors believe each factor is measuring, respectively:

1. The existence of empathy and care within engineering work and practice
2. The importance of empathy and care within engineering work
3. The potential effects of a greater inclusion of empathy and care into engineering,
4. The importance of empathy and care in people relational aspects of engineering work

The items paired to each of these factors and their reliability are shown in Table 7. The bold items included in Table 3, with a few changes to increase reliability of the derived factor structures, make up this four-factor structure. Questions 18 and 19 loaded onto factor one but decreased its reliability (Cronbach's Alpha increased from 0.843 to 0.857 by removing these items). Similarly, question 21 loaded onto factor 4, but Cronbach's Alpha increased from 0.784 to 0.837 by removing this question. Each of these alpha coefficients is in the range of good to excellent, suggesting that the factors are internally consistent.[34] Appendix A shows the numbered items from the survey.

Table 7

Derived Final Factor Structure

Factor Number	Factor Name	Items Paired to Factor*	Factor Reliability
1	Existence in Engineering Work & Practice	23, 24, 25, 26, 27, 28, 29, 30	0.857
2	Importance in Technical Aspects of Engineering	5, 6, 8, 10, 11, 12, 31	0.861
3	Potential Effects	22, 32, 33, 34, 35, 36, 37	0.826
4	Importance in Relational Aspects of Engineering	1, 2, 3, 4, 7	0.837

**see Appendix A for item descriptions*

Factor Structure Descriptive Statistics

Every respondent did not answer every question that loaded onto each factor. If a participant did not answer 6 or more of the questions throughout the entirety of the survey they were removed from this analysis. Table 8 shows the total number of respondents who completed every question on a given factor, the minimum and maximum scores on each factor, along with the mean score and standard deviation. Responses to each question that loaded onto a factor were added together and then divided by the total number of items. This way, responses could be compared on the 1-6 scale used for responses. Because of this, response scores with decimal points was possible. For example, the minimum participant scored 1.14 on factor 2.

By examining mean scores, the highest ranked factor was factor 4, “importance in people relational aspects of engineering”, with a mean of 5.239. This was 0.75 points higher than the next highest factor, factor 2, “importance in technical aspects of engineering”, with a mean of 4.539. The third highest factor was “potential effects” with a mean of 4.320. The lowest scored factor was factor 1, “existence in engineering work and practice”, with a mean of 3.995.

Table 8

Descriptive Statistics for Factors

Factor Number: Factor Name	N	Minimum	Maximum	Mean	Standard Deviation
F1: Existence in Engineering Work and Practice	1528	1.00	6.0	3.995	0.912
F2: Importance in Technical Aspects of Engineering	1507	1.14	6.0	4.539	0.966
F3: Potential Effects	1556	1.00	6.0	4.320	0.900
F4: Importance in Relational Aspects of Engineering	1558	1.20	6.0	5.293	0.675

Figure 1 provides a graphical comparison of these responses. The highest factor is presented first, followed by the second highest, and so on. It is important to keep in mind that a neutral response would be right at 3.5, not 3.0 as participants were not able to report a neutral score on an individual item. Only positive responses for factors 4, 2, and 3 are found within one standard deviation of the mean, whereas for factor 1 just one standard deviation falls in the negative response region.

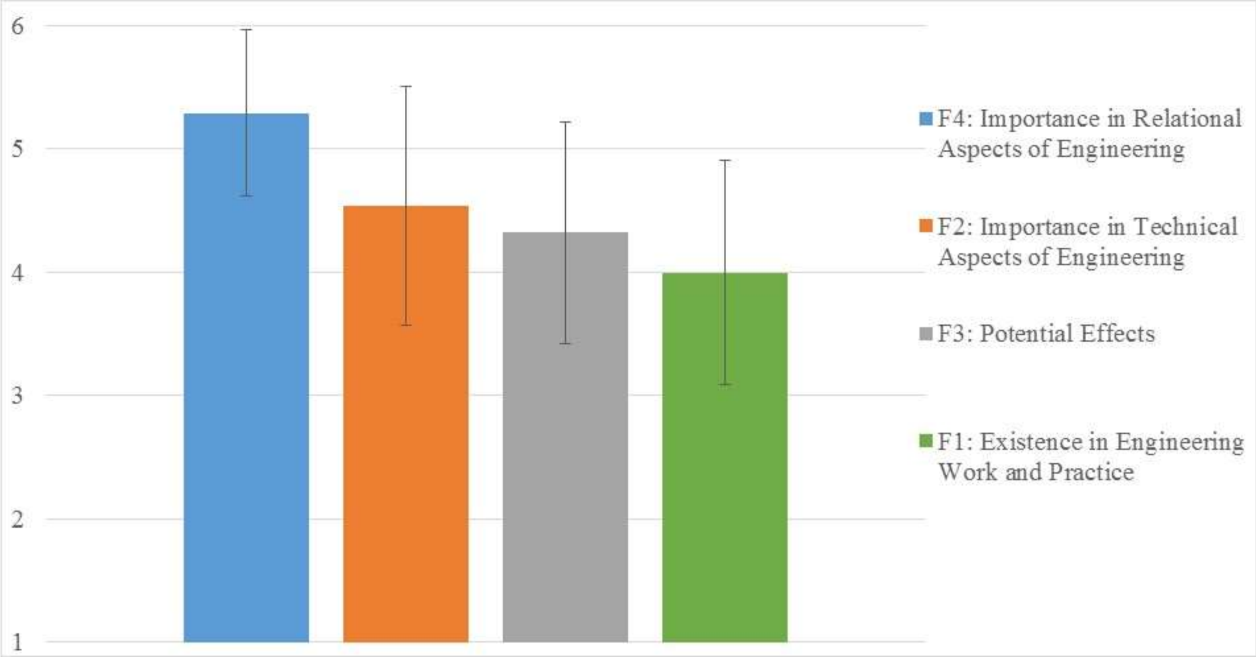

Figure 1: Mean scores on each factor (error bars represent 1 standard deviation)

Closing Discussion

This study showed that empathy and care are distinct multi-faceted constructs, which can be validly and reliably measured within the context of engineering and are important to the practice of engineering along multiple facets. The four-factors derived from this study's Exploratory Factor Analysis all held excellent internal consistency with Cronbach's Alpha scores greater than 0.8. A few questions loaded onto two additional factors that were not reliable. To better understand these nuances, additional questions that may load onto these factors need to be added. The first involved whether or not empathy and care are learnable, and the second involved the innateness of empathy and care.

The highest factor, by far, involved questions pertaining to people relational aspects of engineering. This included communication, working in teams, treating others respectfully, listening, and meeting a client's need. The second highest factor we named the "Importance in Technical Aspects of Engineering". This factor included safety considerations, making ethical decisions, and sustainability considerations. The smallest means corresponded to the first factor, which depicted our participants' current awareness of the existence of empathy and care within engineering. Although this factor was the lowest of the four, its average score was slightly positive showing that most of our participants have slight, but minimal, awareness of the existence of empathy and care within their practice currently. However, roughly one third of the participants scored neutrally or negatively on this factor. This suggests there is much room for greater inclusion of empathy and care into engineering. Based off the first three factors, this greater inclusion may help engineers build stronger relationships and more user-centric technical designs.

Limitations

The participants in this study's survey are potentially those primarily interested in the subject topic, which on one hand may be perceived as a potential bias. In considering the relative importance of the survey items, as we did, and keeping in mind the exploratory intent of the overall study, we believe these potential biases are unproblematic for the findings herein. Nonetheless, this study has been primarily exploratory and should be followed up by studies of confirmatory nature. Furthermore, all the factor structure could be investigated for differences based on (a) gender, (b) age or years of work experience, or (c) engineering profession. These ideas we will explore in the future using these results as a starting point.

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APPENDIX A: SURVEY

This section of this survey pertains to questions about empathy and care in **your engineering work environments (outside of academia)**. Based on your experiences in engineering, rate how important it is for engineers to show empathy and care in the following situations. Select from 1 to 6, considering 1 as “not important at all” and 6 as “very important”.

1. Working in teams
2. Meeting a client’s needs
3. Communicating with others
4. Listening to others
5. Ensuring that a design meets environmental regulations
6. Ensuring that the jobsite/work place is safe
7. Treating others respectfully
8. Making ethical decisions
9. Performing community service
10. In your design work
11. Stakeholder considerations
12. Sustainability considerations

Based on your personal life, rate how important each of these constructs is FOR YOU as an INDIVIDUAL on a scale of 0-100 with 0 meaning "not at all important" and 100 meaning "very important".

13. Empathy
14. Care

Based on your work experiences, rate how important each of these constructs is FOR YOU as an ENGINEER on a scale of 0-100 with 0 meaning "not at all important" and 100 meaning "very important".

15. Empathy
16. Care

Please rate how strongly you agree or disagree with the statement below. Select from 1 to 6, considering 1 as "strongly disagree" and 6 as "strongly agree".

17. I believe traits associated with empathy and care are part of who you are
18. I believe traits associated with empathy and care can be learned
19. I learned to be more empathetic and/or caring during my work as an engineer
20. I learned to be more empathetic and caring during my college years
21. I do not think it is necessary to be empathetic and caring if you want to be successful in the field of engineering. (*Reverse coded for analysis*)
22. I do not think the engineering industry needs to be more empathetic/caring. (*Reverse coded for analysis*)
23. Empathy and care is present in my work as engineer

Based on your engineering experiences in industry, to what extent do you agree or disagree with the following statements? Select from 1 to 6, considering 1 as “strongly disagree” and 6 as “strongly agree".

24 The concepts of empathy and care are well incorporated in my work
25 My bosses value employees that are empathetic and caring
26 My colleagues show empathy and care towards clients when s/he interacts with them
27 My colleagues show empathy and care when we work as a team
28 My professions involves the consideration of empathy and care
29 I am aware of policies on empathy and care at my work
30 I am aware of policies on empathy and care in my profession
31 I believe safety considerations involve caring

If empathy and care are effectively incorporated into engineering, to what extent do you think the following impacts will occur? From 1 to 6, considering 1 as “no impact” and 6 as “very strong impact”.

32 Engineered products will fulfill users' needs
33 Engineered products will be more environmentally friendly
34 There will be more mutual understanding, respect and trust between people involved
35 Engineered products will be more successful in the marketplace
36 Stakeholder considerations will become more central to engineering designs
37 Engineering will attract more females

Upon completion of the survey, participants were invited to participate in a follow-up interview. Participants had the opportunity to provide additional comments at the end of the survey also.