Empathy and care within engineering: qualitative perspectives from engineering faculty and practicing engineers

By: Johannes Strobel, Justin Hess, Rui Pan, Carrie A. Wachter Morris

Strobel, J., Hess, J. L., Pan, R., & Wachter Morris, C. A. (2013). Empathy and care within engineering: Qualitative perspectives from engineering faculty and practicing engineers. *Engineering Studies*, 5(3), 137-159. DOI: 10.1080/19378629.2013.814136

This is an Accepted Manuscript of an article published by Taylor & Francis in *Engineering Studies* on 05 Jul 2013, available online: http://wwww.tandfonline.com/10.1080/19378629.2013.814136.

Abstract:

The purpose of this study was to investigate how empathy and care look within an engineering context from the perspective of (1) existing literature (2) engineering faculty and (3) practicing engineers. The project employed three separate, but interrelated studies, including a summative content analysis of the existing literature, a consensual qualitative research analysis of small group interviews with the engineering faculty, and a consensual qualitative research analysis of written responses from practicing engineers to an open-ended question about empathy and care. Thematic analyses of all three studies demonstrated that although empathy and care appear to have a place within engineering and engineering education – particularly given the current trends in engineering towards sustainability, team-oriented design work, and the renaissance engineer of tomorrow – it appears that conversations and awareness of these two constructs may not often be explicitly stated within the literature or frequently addressed by academic and professional engineers. Results from this study help define the role, benefits, and challenges of framing empathy and care within the engineering field. Our analysis and interpretation regarding how these findings parallel and depart from the existing conceptualizations of empathy and care is specified, and implications for engineers and the practice of engineering in general are discussed.

Keywords: empathy | care | engineering education

Article:

Introduction

This paper explores how empathy and care look within an engineering context by analyzing the related literature and investigating perspectives of the engineering faculty and practicing

engineers. Specifically, we explore the presence and conceptualizations of empathy and care in the existing engineering literature and how engineering faculty members and practicing engineers perceive empathy and care as relevant to engineering practice. We posit that this exploration may be significant to engineering practice, as its insights may contribute to new knowledge about the practice of engineering. Furthermore, it may provide a source for new or restructured learning outcomes for engineering students and may lead into new ways of teaching engineering.

Background

The last 10 years have seen an unprecedented increase in research articles and popular books exploring the topic of empathy. Titles such as 'Mirroring People: The Science of Empathy and How We Connect with Others'[1] and 'The Social Neuroscience of Empathy',[2] both published in 2009, represent two examples of the growing body of the newly emerging science of empathy. Across this growing body of empirical literature, empathy has been considered one of humanity's most basic and powerful capacities, yet – as proclaimed by Baron-Cohen – until recently society and scientists have ignored its '*most valuable resource* in our world'.[3]

By a cursory and unsystematic review of the literature (this paper will present a much more thorough review), the lack of research on the connection between engineering and empathy and/or care is glaring. This comes as a surprise because *empathetic design* is deemed the most comprehensive form of human-centered design[4] and *empathic communication skills* enable engineers to develop personal connections with users and stakeholders.[5] As the world becomes more integrated culturally and environmentally, engineers must adapt to challenges with responsible innovations that embrace ethical and ecological contexts. In other words, they must care that their engineering solutions have a sustainable impact on both people and planet, which requires empathy, defined as the ability to understand what another person is experiencing from within the frame of reference of that other person (we provide a fuller introduction of the terms empathy and care in the following section).

The lack of explicit attention on empathy in engineering is additionally surprising considering the recent calls for holistic engineering education,[6] the renaissance engineer,[7] and the engineer of 2020.[8] Many concepts introduced in these frameworks are strongly related to empathy and care, although this specific terminology is rarely used explicitly. An empathic and caring aptitude may be a prerequisite to '[f]lexibility, receptiveness to change, and mutual respect',[9] 'respect for ways of life different from ours',[10] and 'high ethical standards'. [11] An ability to engage and effectively communicate with 'multiple stakeholders', 'to listen effectively', or to interact with 'increasingly interdisciplinary teams, globally diverse team members, public officials, and a global customer base'[12] requires at least a minimum level of empathy. In essence, engineers need 'well-developed people skills in addition to their ability to solve problems'.[13]

Existing calls for changes in engineering and engineering education stress a need or desire for engineers to work more directly on issues largely related to empathy and care. However, a unified and conceptually cohesive language for applying empathy or care within an engineering context is currently equally missing from the discourse as is an understanding what empathy and care means in the context of engineering. Research on *empathy* and *care* in engineering, informed by long standing traditions in other fields, might provide the necessary rigor, conceptual clarity, and research expertise needed to address our questions regarding how empathy and care show themselves within engineering.

Our primary research objective is to understand how empathy and/or care look when situated within an engineering context from the perspective of (1) existing literature (2) engineering faculty and (3) practicing engineers. The following research questions guide this study:

> (1) How are empathy and care conceptualized and present in the existing engineering literature?
>
> (2) How are empathy and care perceived to be related to engineering practice according to the views of engineering faculty members?
>
> (3) How are empathy and care perceived to be related to the engineering practice according to the views of practicing engineers?

In the following sections we provide a background on how empathy and care are conceptualized in the existing literature beyond engineering, along with how we understand the constructs to complement each other. We present the study in three phases corresponding to the three research questions listed above: (1) a literature review, (2) small group interviews with engineering faculty, and (3) open responses from practicing engineers.

Existing conceptualizations of empathy and care

There is no universal definition of empathy or care, nor is there only one means of teaching these constructs. In order to understand empathy and care and how they may benefit engineering and engineering education, it is important to understand how they are defined both within fields in which they are more traditionally regarded as core concepts (e.g. nursing, counseling, psychology) and within the field of engineering.

Empathy is both a cognitive and an affective process. It involves a person's perceptions, thoughts, and feelings and how those concepts become manifested into a deeper understanding of others. Generally, empathy is considered an internal process that may or may not lead to an external expression of conveyed understanding. Broadly defined, empathy refers to 'the reactions of one individual to the observed experiences of another'.[14] Oftentimes, when defining empathy, authors describe a tension between its cognitive and emotive dimensions.[15] Cognitively, empathy is a process involving understanding the experience of others.[16] Emotively, empathy is

understood as ‘the capacity to enter into or join the experiences and feelings of another person’.[17] Providing a comprehensive synthesis of existing conceptualizations of empathy in a variety of fields and situating them in the domain of nursing, Kunyk and Olson found five conceptualizations of empathy to exist: ‘empathy as a human trait, empathy as a professional state, empathy as a communication process, empathy as caring, and finally, empathy as a special relationship’.[18] As these distinctions show, even in fields where empathy is frequently used, it is a complex and nuanced construct.

Empathy may be understood as an ‘automated response’[19] potentially evoking the mimicry of another person’s behavior,[20] which in turn leads to an enhanced interaction between individuals[21] and/or the development of harmonious social relationships.[22] Without empathy, these interactions and relationships cannot be developed. Therefore, empathy may be necessary to the evolution and survival of social groups.[23] Preston and de Wall suggest that as ‘ultimate bases’ empathy occurs through one’s ‘response-oriented nervous system’ and is a ‘perception-action process’.[24] The likelihood that human subjects will help overcome an occurring distress depends on the subject’s ability to solve the problem in the first place. This likelihood also depends on ‘a complex cost/benefit analysis on the perceived effectiveness’ of the human subject helping the object, where if the cost is higher than the benefit the subject is likely to refrain from helping the object. In this sense, empathy is an instrument crucial to decision-making processes.

Care is a similarly complex construct, involving both feelings and actions. It is a concept that dwells in the intentions and actions of people who are pursuing the well-being of something, whether it is another person, the environment, the general public, the goals of a company, the values of stakeholders, or their own personal interests. One widely held understanding of caring is ‘helping the other to grow’[25] and is intrinsically rewarding to the caring individual.[26] If we care about an object, no matter what our interpreted results of a cost/benefit analysis is, the likelihood that we will evoke helping behavior is higher than if we were not to care. The more we care, the more likely we are to take action. Thus, when Kunyk and Olson define ‘empathy as caring’ they pair understanding ‘of the client’s situation’ with ‘a compulsion to act’.[27] While empathy and care are often considered to be related (e.g. empathy leads to caring, caring leads to empathy, one trait is a component of the other), one unanimous consensus on *how they are related* is non-existent. Berenguer shows that an increase in empathy for another person or natural objects leads to an increase in willingness to actively help that person or the environment.[28]

Following the existing conceptualizations, in our study, we understand empathy to be largely an epistemological construct (‘What do I need to know about another person?’) with abstract and theoretical connotations (‘How do my actions affect other people?’).We understand care ontologically (‘I *want* to act upon my understanding of other people and their need.’) with pragmatic connotations (‘Here is what I am actually going to do.’).

Empathy, care, and engineering education

Engineering education has traditionally focused on a set of technical skills, such as problem solving, design, and modeling.[29] Although these skills are core and important, future engineers must also be able to 'adapt to rapidly changing work environments and technology, direct their own learning, broaden an understanding of impact, work across different perspectives, and continually revisit what it means to be an engineer'.[30] Specifically, future engineers need to develop specific character qualities, affective dispositions, and habits of the mind.[31] Holistic engineering education includes promoting traits such as these in order to 'develop the capacity to hear and to develop relationships that provide the basis for partnering to solve problems, both within the academy and without'.[32] Sheppard, Macatangay, Colby, and Sullivan summarize the need for holistic engineering education:

> Historically, the engineer's assumed perspective was outside the situation or problem – that of a disengaged problem solver who could confidently model the problem in objective, mathematical terms and then project a solution, framed largely in terms of efficiency and technical ingenuity, affecting a system uncontaminated by the frictions of human relationships or conflicting purposes. […] Because engineers' work directly affects the world, engineers must be able and willing to think about their ethical responsibility for the consequences of their interventions in an increasingly interlinked world environment. Working with others, in this country and around the world, to understand and formulate problems, engineers are immersed in the environment and human relationships from which perception of a problem arises in the first place.[33]

Previous research

In a pilot literature review, our results suggested that the use of empathy and/or care in engineering is rare as we found only 22 empathy-related and 16 care-related engineering papers that explicitly used these terms.[34] Nearly half of these papers were within the domain of Engineering Education (as opposed to papers produced within other technical disciplines in engineering). While empathy and care are core components of professional standards in fields such as counseling and nursing, this was vividly not the case in engineering. Furthermore, an exploratory study found that faculty from helping fields were comfortable asserting that engineers *do not* base their work around empathetic or caring considerations. These empathy/care experts suggested that the public likely held similar stereotypes, although these participants believed a focus on empathy and care might ebb away such impersonal and gender conceptions.[35]

Methodology and interpretive findings

The following research questions guided this study:

> (1) How are empathy and care conceptualized present in the existing engineering literature?

(2) How are empathy and care perceived to be related to engineering practice according to the views of engineering faculty members?

(3) How are empathy and care perceived to be related to engineering practice according to the views of practicing engineers?

We follow a multi-step qualitative methodological approach corresponding to the three research questions, where in Phase 1 we conducted a systematic literature review guided by the summative content analysis.[36] In Phases 2 and 3 we employed consensual qualitative research.[37] The specific data collection methods we used, corresponding to each phase, include: (1) Literature review, (2) Small group interviews, and (3) Open responses. In all phases we employed thematic analysis.

Phase 1: literature review

Data collection

Phase 1 is an extension of a previously conducted literature review that examined how empathy and care were explicitly presented within the engineering literature.[38] During this current study, we explored research studies which contained key concepts and attributes of empathy and care, yet did not explicitly use the terms. By exploring the literature explicitly including empathy or care, we generated a keyword list of terms used frequently alongside these terms. These keywords include 'build trust', 'compassion', 'helping profession', 'humanitarian', 'humanized', 'safety', 'solidarity', 'community involvement', and 'user's need'. Using these keywords, we conducted a literature search in engineering literature databases such as IEEE's Xplore and Compendex (Engineering Village), which included major publications of engineering education such as the journals JEE, IJEE, and the conference proceedings of ASEE and FIE. We collected 106 papers in total.

Data analysis

We analyzed the collected papers through a summative content analysis approach where we began by 'identifying and quantifying certain words or content in text with the purpose of understanding the contextual use of the words or content'.[39] After identifying articles that employed the aforementioned keywords, we next analyzed how these words were defined in our collected references. We opted to focus our exploration *only* on 46 of the 106 collected papers as in these papers variables and keywords around empathy and care were explicitly defined. Table 1 shows the number of papers we collected and analyzed paired to each keyword.

Phase 1 findings

Findings of this literature review suggest that empathy and care are rarely explicitly represented in engineering education literature, although associated terms are used more commonly. Specifically, the eight keywords in Table 1 seem to embody implications of empathy and care

while neglecting the use of the terminology, perhaps due to the lack of conceptual clarity or the lack of an explicit discourse on these concepts. In other words, this 'alternative' terminology highlights areas of discourse which seem to overlap with empathy and care, as conceptualized in this study. The following paragraphs describe the application of each of these alternative keywords as found in the literature.

First, 27 articles addressed the category of *humanitarian* engineering. Humanitarian engineering is 'the application of engineering knowledge and skills to communities in need'.[40]

Table 1. Summary of articles found.

Keywords	Number of papers collected	Number of papers analyzed
Humanitarian	27	9
Safety	19	7
Build trust	13	7
User's need	12	4
Compassion	9	6
Solidarity	9	5
Humanized	9	3
Community involvement	8	5
Total number	106	46

It requires 'a balance of technical excellence, economic feasibility, ethical maturity, and cultural sensitivity' and aims to 'directly improve the well-being of underserved populations'. 41 Constraints for humanitarian design may be 'physical, economic, environmental, legal, political, cultural and ethical'.[42] In the editorial of the special issue on *The Role of Information and Communication in the Context of Humanitarian Service*, Haselkorn and Walton argue further that engineers should apply their skills to the needs of the humanitarian sector, from 'helping to establish effective and sustainable infrastructure to helping provide food, shelter, and improved medical care'.[43]

Second, another 19 articles addressed the issue of *safety*. To a large extent, these articles simply suggested the design of engineering products should take users' safety into consideration[44] and that engineers should focus their attention towards preventing and addressing hazardous or injurious accidents which may occur as a result of their type of work.[45] These conceptions of safety were commonly utilized in a managerial context or through discourse of liabilities.

Third, *building trust* was mentioned in 13 of the collected articles. Trust is needed between engineers and customers,[46] between different working groups,[47] and is regarded as one of the 'baseline non-technical skills for team members'.[48] Brown, Flick, and Williamson suggested building trust was one of the important components of social capital that must be taught in engineering.[49] Derro andWilliams summarized the competencies and associated behaviors of highly regarded systems engineers at NASA, which included respect, credibility, and trust.[50]

Derro and Williams saw ‘trust of self and others as a pervasive element required to achieve success’.[51] Behaviors which help individuals gain respect, credibility, and trust include using a respectful tone, words and body language, following through on commitments and serving as an advocate for the team, understanding and appreciating the challenges others face, demonstrating personal integrity, conducting business in an honest and trustworthy manner, treating team members fairly, and more. Similarly, Siemieniuch and Sinclair argued that the quality of trust depends on a number of things, including establishing common goals, being transparent about problems and ways of working, and more.[52]

Fourth, *user’s needs* were discussed in 12 of the articles. This literature indicated that engineers should design products to satisfy the users’ need, and that what the users’ need should be identified in the early stages of design.[53]Various techniques, including interviews, scenarios, and questionnaires are used in order to elicit such needs.[54] Empathetic design is deemed the most comprehensive form of human-centered design and engineers employing empathetic design are particularly concerned with holistically understanding human beings as something more than just a user of a system, as somebody who carries unique needs and wants not addressed by the particular design.[55]

Fifth, 9 of the articles explicitly discussed *compassion*. Here the notion was that effective engineers must understand ‘how technical solutions will fit into context; this requires a level of understanding and compassion for those who will benefit from engineering design activities’. [56] Moriarty and Julliard suggested compassion is a virtue ethic for engineers, ranging from care for individuals to care for processes or products. They argued that the decisions engineers make are always ‘a combination between objective criteria and subjective reflection’ and that products designed with a sense of ‘care and compassion for the other in a social context’ is ideal.[57] Burke, De Paor and Coyle postulated when ‘students recognize that engineering can have a positive impact on the lives of those who were disadvantaged or socially excluded, they gain a sense of professional responsibility and compassion’.[58]

Sixth, another 9 articles discussed *solidarity*. Here the notion was that ‘teamwork and group solidarity are crucial for project success’.[59] Unger suggested that lack of solidarity leaves engineers ‘exposed to career damage’, and that the solidarity may be grown through participation in a larger community beyond the employer (e.g. engineering organizations, professional societies, unions).[60] Lynn found that Japanese engineers show solidarity by staying ‘late at the office’ with their co-workers, and noted that this should be seen as a strength rather than a marker of inefficiency.[61]

Seventh, nine more articles discussed the concept of *humanized* engineering or design. In humanized design, engineers take ‘physiological, psychological, behavioral and cultural factors’ into account.[62] Humanized design originates from a focus ‘on the needs of human being in modern age’.[63] Yong and Shan argued that a humanized system should be able to integrate the ‘Kansei characteristics of human such as affection, feelings, emotions’.[64] Jian, Shang,Yu, Li, and

Zhao regarded humanized design as to design something by 'exploring human nature and application of human behavior, abilities, instincts limits and other characteristics and to create a meaningful human-computer interaction'.[65] In addition, Guo, Cao, Ye, and Guo pointed out that a humanized design must be environmentally savvy.[66]

Lastly, community involvement was discussed in 8 of the 106 collected articles. Some authors suggested that involvement at the community level adds a local context to the engineering solutions, thereby catalyzing the engineer's ability to help local community members solve a pressing need.[67] Community involvement may occur throughout all levels of the product development process; needs-identification; brainstorming; concept evaluation; prototype testing; evaluation and iteration. Local residents may be involved in the projects by participating in surveys and interviews conducted by engineers.[68] The absence of community participation may result in the loss of opportunities for working towards social justice.[69]

Phase 2: small group interviews

In phase 2, we explored what empathy and/or care look like in an engineering context from the perspectives of engineering faculty by conducting small group interviews.

Instrument

The research team developed an interview protocol and interviewers were guided by these questions: (1) What does 'empathy' mean? (2) What does 'care' mean? (3) How much importance is placed on care and empathy…in your field? In your research? In your profession? In your teaching? and (4) Is there value to integrate care and empathy into the curriculum? How is this accomplished?

Data collection

We conducted three engineering interview sessions with a total of seven engineering faculty members (Interviews 1, 2, and 3 had 3, 2, and 2 participants, respectively). The small group interview sessions were semi-structured and audio recorded. In total, seven all male engineering faculty members from civil, environmental and ecological, aeronautical/astronautical, electrical, and industrial engineering participated in the interviews.

Data analysis

To analyze the interview transcripts from phase 2, we inductively developed a coding scheme through several iterations, a process known as 'categorical aggregation'.[70] We developed and used six coding categories to capture themes from the data. We used the frequency of codes to discover patterns from responses, develop themes inductively from the data, and to bring to light any relevant contradictory views.

After one member of the research team (Coder 1, a male PhD student in Engineering Education) finished coding the data and developed a rigorous coding scheme, a second member (Coder 2, a female Master's student in Counseling with some undergraduate experience in engineering) engaged with the data, agreed or disagreed with the codes set by Coder 1 and added codes thought to be 'missed'. The independent coding process gave each coder the freedom to assess the statements in their own understanding of the transcription. Coder 1 initially coded 186 items. Coder 2 suggested 98 additions and 19 removals for this initial pool. Coder 1 reviewed the suggested additions, accepting a total of 56 items. After revisiting the remaining items Coder 1 believed should not be included, Coder 2 revised her editions and agreed or disagreed with the removal suggestions. The final total number of unsettled disagreements was 21 of a total of 242 items coded, giving an overall agreement of 91.3%, which is considered a high-level of inter-rater reliability.[71]

Phase 2 findings

The final coding scheme from practicing engineers' responses consisted of 6 themes and 58 categories. Table 2 lists these six themes and provides a description of each theme. In the following passages, these six primary themes are further explored. Statements in quotation marks come directly from the small group interviews.

Contrasting conceptualizations of empathy and care

Engineering faculty suggested empathy has both an understanding (e.g. cognitive) and an emotive component. Most definitions were similar to one participant's definition of empathy as 'the ability to put yourself in someone else's shoes' and another's, 'relating to other people's feelings'. Participants considered care as separate from empathy and involved actually doing something about a situation. One participant stated, 'Maybe empathy is a feeling, but caring is more of an active process'.

One participant believed empathy helps 'when you interact with other people'. Another stated, 'People skills are the ones…being able to communicate well, ask questions, and be able to put yourself in someone else's shoes to see if you can relate to what their situation is'. Another elaborated on his perspective while discussing design teams:

When I tell a design team that that's the team you might be working with and you are going to have to figure out to work with them…So now you have to start learning the person…why does that person do what they do and how can you start working with that person, and even though that person is dominating, you know where that person is coming from…The team can't work if you don't understand what the other person is really thinking, what drives them…So when they (students) come to me, that's what I tell them. I don't use the word caring or empathy, but that's what the word is about. If you don't know how to do it, you can't win…

Lacking leads to the hindering of inter-activities

Engineering faculty thought the absence of empathy was even more detectable than empathy itself, as they perceived situations where a conflict arises to represent a lack of empathy or care. To determine if students were acting empathetically, one participant suggested:

> I guess you'd look at the sorts of conversations that they are having and the role that they are playing in those conversations - whether they were seeking out that relational aspect that was indicated or whether the conversations are more self-centered.

Table 2. Themes and descriptions from interviews with the engineering faculty.

Theme	Description
Contrasting conceptualizations of empathy and care	Empathy aligns with other abilities which are important for engineering students to develop, such as understanding the perspective of another person, relating to another's feelings, collaborating effectively, or communicating with clarity. Care is more complex, although similar to empathy in many respects. Fundamentally, care involves action while empathy does not
Lacking leads to the hindering of inter-activities	A lack of empathy or care is detrimental to the proper functioning of inter-activities, such as working in design teams or solving multi-disciplinary problems
Intrinsic holism	Viewed normatively, or considering the roles that engineers play in improving the society as a whole, engineering as a profession is intrinsically empathetic and/or caring
Motivating students to learn	Empathetic and caring engineering educators increase students' motivation and learning, insofar as they are able to relate to their students and show that they care
Indirect curriculum embedded-ness	Indirectly, empathy and care are already included in engineering coursework, and enhancing these abilities or dispositions might involve enhancing certain skills. However, the two abilities or dispositions themselves do not deserve courses focusing specifically on their development
Valuable, but not absolutely necessary	Empathy and care are valuable skills or dispositions for students to develop, although they may not be necessary for one to succeed as an engineer

Another participant questioned, 'What kind of problems do you normally get in a team? One guy is trying to tell everyone else what to do…That certainly demonstrates a lack of empathy'. Another participant added that no conflict in a situation projects more happiness, which must be contained within 'an environment that probably is caring'. One of the academic engineers explained in detail:

> I get all the problems when people are not happy, including design teams…if we just focus on design part…only one person does the work or they can't work together and they complain. And so, usually, it is a problem, it is empathy, I think that some people

> feel that someone is dominating, I can't do a thing, because this selfishness of some people.

Intrinsic holism

One participant reasoned, 'You could make an argument that pretty much all of engineering is about improving society, and therefore at some level there is some element of empathy and caring'. They later continued, 'Engineering provides devices and systems that improve the quality of life of civilization'. Another participant initially viewed the constructs on the 'person to person engagement end'. However, towards of the end of the interview, this participant re-framed their initial understanding:

> If you take a broader conception about what does it mean to turn empathy into a solution that provides real care in circumstances, then there are lots of examples of what engineers have done. Some not so good, some that have been absolutely foundational in terms of capacities of communities to care for people. Now the engineering realm might well be at the person-to-person end of that but it's still playing a significant role in the overall process of caring. Even down to those who work on improving crop yields and those sorts of things, so there is enough food in the world to feed people.

In response to a query on an outsider's perceptions of engineering as being empathetic and/or caring, one participant stated, 'I don't know if people would explicitly think about empathy and caring, but I think it's the recognition that the technical contributions benefit their lives'.

Another participant supposed empathetic or caring engineering occurs whenever a project's success depends on inter-disciplinary relations amongst engineers. 'That's what engineering is all about; it's how to bring it all together, right. So it is actually empathy and caring about the other subjects to get it to work'. Another participant suggested many of their fellow faculty show care through 'communal service' and 'perhaps the sustainability emphasis provides some sort of way of thinking about caring for the environment'.

Motivating students to learn

The academic engineers thought empathy enables them to understand their academically diverse student population and that effective educators need this skill. As one participant stated, 'It's important to understand their [students'] perspective to help them'. Participants suggested this understanding allows teachers to adequately assist students in need of a more direct and personalized intervention, which they perceived or described as an active form of caring. As one participant stated, 'The empathy there is understanding what level they [students] are at and how to bring them to a point where they can understand'.

One participant, a faculty member and engineering academic advisor, discussed the presence of empathy in a situation involving another professor and a student. The student was struggling

academically due to medical issues beyond her/his control. The student's professor brought the student to this advisor, an *act* of care. As the participant stated, 'The impetus was the feelings of empathy but the professor wanted to follow through with it and bringing the student to me for action was the caring part.' This participant later explained,

> I think someone who doesn't feel sorry for someone doesn't have a chance of showing empathy at all, because they can't relate to the situation at a personal level. So this professor, was relating on a personal level…if this was happening to me, how would I want to be treated? The student didn't want special consideration…just wanted a fair shake. The empathetic professor agreed with that, this situation calls for some special consideration so you don't fail the class because you were too ill to attend school for a few weeks.

Indirect curriculum embedded-ness

Several participants noted the best way to incorporate empathy/care into engineering curriculum is indirectly. One participant reasoned, 'I think for us there is a place, right, it is in a design class…the teamwork part of the design class.' Another participant stated 'that it exists in the curriculum already and different ways and it could be discussed more openly, but I don't see us having a course on it'. Although one participant claimed, 'Our classes are adamantly, adamantly, technical and that's not going to change' the participant later stated, paradoxically, 'That's what industry expects from us…well-trained engineers who can work in a team and who can communicate and who can have empathy for their teammates and who can work well with them'.

Valuable, but not absolutely necessary

One engineer speculated that having these skills were 'a plus but it's not what is really necessary' to be a 'good engineer'. In two of the three sessions, engineering faculty participants tended to vacillate between minimizing and dismissing the presence of care/empathy within the practice of engineering (industry and academic) – although not explicitly stating whether or not they personally believed it should be present or not. For example, when asked, 'How much, would you say is an emphasis in your field of work placed on empathy and care?' an engineering participant responded, 'I suspect that my colleagues would deny any such thing'. When asked, 'Why?' the respondent continued, 'Oh, because, you know, most of them are guys and most of them are engineers and it's not part of the engineering culture'. In another session, a participant suggested, 'I think there's a perception…to be really successful you have to be tough as nails and maybe suppress being a nice guy'.

Still, another engineering participant suggested the presence of empathy and/or care 'depends on the personalities involved'. Throughout the discussion, this participant revised his own reasoning. Initially, this participant suggested empathy and care are present 'at the professional level, very little. When something has to get done, something has to get done…it doesn't matter what you're going through, you'll have to perform, otherwise you're going to pay the

consequences'. Yet, later in the conversation this participant reflected on a project intended to aid soldiers and stated, 'I guess in terms of motivation for the project and the end result, empathy was maybe the motive'.

Phase 3: open responses

In phase 3, we further explored how trained engineers believe empathy and/or care look within an engineering context by analyzing open-ended responses from practicing engineers.

Data collection

The participants of phase 3 were practiced engineers (n = 348; 15% female, 84% male, four did not specify), alumni from our home institution working in a variety of different fields with at least 1 year of experience in practicing engineering (n = 338). By using an alumni list, we sent out an e-mail to these alumni, soliciting comments in regard to their perceived importance of empathy and care in engineering. The prompt received comments ranging from a single sentence to a few paragraphs.

Data analysis

Thematic analysis, which is 'a method for identifying, analyzing, and reporting patterns (themes) within data',72 was used to analyze the engineering alumni's comments. One member of the research team (Coder 1, a female PhD student in Engineering Education) first inductively generated an initial set of codes by generating themes, categories, and instantiations through an analysis of the first 150 comments. She next applied this rigorous coding scheme to code the whole dataset. After Coder 1 finished coding, a second member (Coder 2, a male PhD student in Engineering Education) engaged with the data and (1) agreed or disagreed with the codes paired with data, (2) refined codes and added codes that were thought to be 'missed'. Coder 1 initially coded 563 items. Coder 2 used Coder 1's initial results to independently evaluate the comments. Coder 2 suggested 161 additions and 37 removals to this initial pool, giving an initial agreement rate of 72.7%. After Coder 2 finished adjustments, Coder 1 reviewed those changes and agreed or disagreed with the changes. The inter-rater reliability increased to 96% after the round 1 adjustment.

Table 3. Themes and descriptions from short responses by practicing engineers.

Theme	Description
Conceptual vagueness	The terms empathy and care are not parts of the engineers' regular vocabulary as 20% of our respondents requested further clarification of the terms and 4% did not feel comfortable providing any insight without a provided definition
Importance in engineering-relevant human relations	Empathy and care are important and needed in three human relational respects relevant to engineering: client relationships, leadership and management, and while working in teams

Role of empathy and care in communication-related attitudes and behaviors	Exemplary empathy and care communicative behaviors consist of showing respect, listening to others, conveying one's understanding of others, and communicating with other people in general
Application in product development and design	Empathy and care are present in product development or design when it comes to meeting clients' or stakeholders' needs and safety considerations, although there is a tension between clients' needs and clients' wants. To a lesser degree empathy and care are inherent in product development when it comes to environmental concerns, ethics considerations and bettering people's lives
Utilitarian perspectives	If engineers do not perceive empathy or care as having utilitarian advantages, such as producing economic gains, developing products more effectively, solving problems objectively, or enabling professional development, they see empathy and care as unimportant or even irrelevant
Embedding in the work culture	Empathy and care would be valued more if it they were part of the requirement of the job, or if they were promoted by the direct supervisor and/or company

Phase 3 findings

The final coding scheme of engineering alumni's comments consisted of 14 themes, 54 categories associated with themes, and 31 instantiations. Here we explore these six major themes most commonly represented within the comments. 76% of the text contained one or multiple categories and/or instantiations corresponding to these themes. Table 3 lists these six themes and provides a description of each theme.

Conceptual vagueness

Many respondents were uncertain about the meaning of empathy and care and asked for a definition of the terms. For example, one respondent commented, 'I think it would be helpful to define the terms "empathy" and "care" and what the differences are'. Many respondents who asked for clarification still provided additional insights. As one respondent stated:

> I would suggest more clarification of terms when soliciting this information. Empathy implies a relationship with another human being. Care can relate to other human beings, or it can also refer to other aspects of the engineering profession, such as care in complying with design guidelines, engineering practices, etc.

Many participants pointed to the lacking use of this terminology in engineering discourse. One respondent summarized:

> I happen to have strong positive feelings for these things, but I know for sure that most engineers do not, and probably do not even know what the word empathy means, and consider caring to be some sort of wimpy feminine thing.

One respondent suggested that engineers do have understandings of the terms, but lack conceptual clarity for application. This participant offered that perhaps this is because the definitions vary with context, ‘The concept of caring and empathy vary significantly depending on where the engineer is working’. A separate participant elaborated on this idea: The concept of caring and empathy vary significantly depending on where the engineer is working. For example, the engineers I work with in Brazil require a relationship of caring and to a degree empathy before an endeavor can be successful. On the other hand, a German engineer can work side by side with another engineer and have no idea what their hobbies are or if they have children. Respect of their engineering abilities is seen as a higher importance.

Importance in engineering-relevant human relations

The engineering alumni thought it was critical for engineers to show empathy and care when interacting with clients, as one respondent reasoned, ‘My company has an enormous emphasis on caring and empathy, not just for the end customer but for every internal customer of your immediate job’. Another respondent emphasized the necessity and importance of empathy to their job, ‘I work in a very specialized field that deals in a highly intimate and complex hardware-to-human interface. I have to have empathy with my customers or I fail at my job’.

The engineering alumni recognized that empathy and care were indispensable when they were in a managerial/leadership role. One participant equated ‘seasoned project managers’ with ‘empathetic people’, while another suggested, ‘Any manager of others needs to live on empathy and caring’. One participant talked from their own experience:

> I have been an engineering manager for 15 years. The importance of empathy and care in the engineering environment and in the engineering processes became apparent as I transitioned to a manager role. It is very easy to underestimate the value of these two attributes.

Some participants suggested upward mobility hinges on empathic ability, as a participant wrote, ‘I believe one develops greater empathy and caring the longer one is in the field and “moves up the ladder” to greater management responsibility’. Another added, ‘I believe based on personal relationships and working well with others through empathy and genuine caring, I have been able to move up and around within the company’. Another quoted a past professor who stated, ‘There are more engineers fired for inability to get along with people than for technical incompetence’.

The importance of empathy and care in teamwork was also mentioned in the engineering alumni’s comments, as one respondent said, ‘To the degree that increased empathy promotes more participation of all members of an engineering group, then I believe it leads in general to better outcomes’. Another participant stressed the benefits of empathy and care when present in teamwork, ‘With empathy and care, engineers can feel more open to discuss and show their work to others early, rather than wait for a dreaded peer review or even customer review to find flaws’.

Role of empathy and care in communication-related attitudes and behaviors

Some participants thought the importance of empathy and care lies primarily in the domain of communication. One participant wrote, ‘I find that many engineers lacking in these skills have a difficult time communicating with others, and this is where we get the typical engineer stereotype’. Another participant saw empathy and care as essential to ‘improving communications and interpersonal skills’ in general. A separate participant elaborated on this idea:

> They [empathy and care] can come into play with communication with a customer as the engineer should take care to listen to the customer to clearly understand the customers end requirements; this can be especially important when some requirements come into conflict with others.

One participant distinguished between empathy as understanding others and agreeing with them.

> A young, immature person typically believes empathizing with them [others] means that you have to agree with them. It doesn’t, it means that you listen to and respect their opinion. As a long term engineer and manager of high performance teams, I believe that the more commonly called ‘communication skills, collaborative, working across different cultures, and mutual respect’ are the business terms equivalent to the softer terms ‘empathy and caring’.

Application in product development and design

One respondent stated, ‘Being caring and empathetic does not mean letting people take advantage of you. It means seeing things from their point of view, which can make our products more customer-driven’. Another respondent put more emphasis on safety implications, ‘Engineers should read and practice the Cannon of Ethics for Engineers. This outlines the needs for engineers to care for the safety of the public in performing their duties as an engineer in the profession’. Yet, some of our respondents recognized a tension between the clients’ needs and the clients’ wants, especially in regard to safety considerations. They agreed that priority should be given to clients’ needs, but as one respondent argued, ‘Accomplishing real safety designs often require very little empathy for someone’s preferences versus their needs for safety’.

Empathy and care were considered present in product development insofar as environmental concerns, ethics considerations, or bettering people’s lives were taken into account. One participant stated, ‘An engineer MUST care about what they are doing as we often develop products that try to better peoples’ lives’. Another echoed, ‘Engineers are considering more things that the customers have requested like sustainability, environmental impact, consumer safety, etc., now than was done in the past’. Although not empathy and care per se, another respondent speculated that their company focuses on empathy/care through similar phenomena. They wrote, ‘[Our company] provides numerous hours of training to instill these concepts under

different manifestations (ethics, conflict of interest, level of care, attention to detail, achieving excellence, etc.)'.

Utilitarian perspectives

One participant asked, 'How would someone answer if the question [regarding the importance of empathy and care] mentioned an investment of time or a sacrifice of some profits to achieve the additional empathy and care?' Another participated stated, almost as if in reply, 'I'm not sure what would be more effective, a caring empathetic person that doesn't produce results, or someone who is really not that empathetic but produces great results'. As a whole, the engineering alumni seemed to suggest that empathy and care are not as important when they conflict with other, more primary factors. Most respondents attached the greatest value to economic gains, as one participant stated, 'Engineers frequently must deliver profitable design to meet business demands. Empathy and care do not enter into the designs as much as cost and liability'. The bottom line is the driver, as another participant stated, 'Business drives engineering, not the other way'. Another respondent who suggested empathy and care align closely to engineering ethics suggested that:

> The moral impact of empathy or care is of necessity minimized in the engineering solution of task assignments. Choices presented in the engineering of devices must be based on the goal and the task to be performed. If moral and ethical questions cloud judgment, factual solutions cannot be reached.

Another respondent, who believed that empathy and care were important, pointed to the inherent difficulty, 'I think that there is a danger in being too empathetic to groups or clients and not remaining objective'. The issue becomes one of too much empathy, or too much care, to resolve a given engineering challenge.

Embedding in the work culture

The engineering alumni stated that whether engineers perceived the importance of empathy and care depended on the values emphasized by the company or the supervisor. For example, respondents stated, 'I think that the impact of care and empathy on the engineering process depends a lot on the particular company and its management style', and, 'An individual's empathy is molded by the bosses' values and directions, as is the group's reputation for caring and empathy'. It seems that empathy and care would be valued more by engineers if they come from the overhead leadership. Another respondent suggested, 'These concepts need to be established from the top down in organizations, and everyone in the chain needs to exhibit them, and not just when convenient or expedient'.

A business owner in our study touted empathy and care as essential qualities in terms of developing a business, but noted that the difficulty with the constructs is their unquantifiability. The owner wrote:

> I could not have the customer base I have, nor could I successfully function in the international marketplace without empathy & care. The 'devil is in the details' and that is especially true when relating to people and trying to capture and build a customer base. Empathy is necessary for really understanding people, but may not be a marketable measureable metric that value can be placed upon in the marketplace.

Discussion

Empathy and care have a strong presence in engineering practice, although these terms have lacked conceptualization and a coherent framework for their application and development.[73] Existing engineering literature indicates relative value of these notions embedded within similar vocabulary, yet this literature rarely uses the terminology explicitly. Similarly, the terms 'empathy' and 'care' are uncommon vocabulary for practicing engineers, as 20% of our respondents requested further clarification of the terms, and 4% were not comfortable providing any insight whatsoever without a provided definition. Yet, despite the fact that many of our participants encountered these terms for the first time, the majority of these participants were able to strongly relate to the sentiment carried by the terms. Furthermore, our participants seemed to find the terms useful and at times even very welcomed new analytic devices to reflect and find new insights into their profession. The practicing engineers' insights lead to the development of a complex web of findings highlighting variance across participants as to how they perceived the value of these constructs within their work. To deconstruct this complexity, we now discuss this study's findings in comparison to the five conceptualizations of empathy found by Kunyk and Olson as described in our background section, 'empathy as a human trait, empathy as a professional state, empathy as a communication process, empathy as caring, and finally, empathy as a special relationship'.[74]

Empathy as a human trait suggests that empathy is innate and can only be identified and refined. The engineering faculty members never explicitly discussed this notion, and practicing engineers did not stress on it. Engineering faculty seemed to assume that empathy may be intrinsic to certain acts, although it was unclear whether the faculty believed that specific pedagogies would lead to the development of empathy as a novel trait or the reinforcement of an empathic disposition which an individual already possessed.

Empathy as a professional state identifies empathy as a way of being; rather than defining empathy as a trait, individuals may be trained towards an empathetic state. This notion aligns with the thinking of our participants, for example, when the engineering faculty presupposed empathy may be cultivated in team-oriented activities. Rather than focusing on the pragmatic *how* empathy or care may be cultivated, participants (faculty and practicing engineers) discussed the abstract *why* empathy and care should be cultivated in the contexts of success, professionally or academically. In so doing, our participants seem to perceive empathy as a utilitarian construct,

having value insofar as it provides some edge, be it in terms of promotion, advancing administrative ranks, or better meeting a client's need. The comments provided by practicing engineers suggested such sentiments and practices represented by empathy and care are an essential part of engineering, inseparable from other skills and attitudes. Furthermore, as our participants indicated empathy and care are integral to the core of their engineering practice, our research cautiously supports the notion that these terms are not easily placed in the dichotomy of 'hard and soft skills'.

Empathy as a communication process defines empathy as an integrated three-step process of (1) the internalization of another person's perspective, (2) expressing empathy through communication and (3) perceived empathy by the other party involved. Both engineering faculty and practicing engineers suggested that empathy requires and enables greater understanding of people, and better communication skills, and thereby was beneficial to team-oriented activities (within a working team) and working with clients or other stakeholders. Our participants are again speaking of the utility of empathy, this time specifically in the process of communicative activities.

Empathy as caring merges an action component with other conceptualizations of empathy. Our participants tended to differentiate between the two constructs, empathy and care, which may be due to the framing of the study – we asked them to separately conceptualize the two concepts. Caring, as seen by our participants, involved the act of doing. While empathy – in their conceptualization – represented more of an attitude and a disposition, practicing engineers did not describe empathy as an abstract feeling, but had very concrete ideas of how empathy appears in their workplaces and what empathetic activities entail.

Empathy as a special relationship is defined as a reciprocal relationship two individuals develop over time where empathy is present, cultivated, or visible within one-on-one, person-to-person relationships. In our study we saw two different conceptualizations of this special relationship: (1) Empathy was defined at a broader, macro or societal level, in which engineers take the perspective of an unspecified abstract group of users or stakeholders such as 'one million users cross this bridge'. In this perspective, the consideration of the perspective of a single user gives way to an aggregate perspective. (2) One-to-one oriented conceptualizations existed in our study as well, although emotional components of special relationships were rarely mentioned and never stressed. Compared to Kunyk and Olson's conceptualization of *special relationship*, engineers tend to view one-to-one relationship-oriented empathy through utilitarian connotations. In this perspective, the other is seen as a means to achieve goals extrinsic of the other person. As an example, instead of asking, 'How might empathy and care enable me to help the other?' our participants may ask (sometimes, but not always explicitly), 'How might empathy and care help me in terms of becoming successful, delivering reliable products, or designing solutions?'.

In sum, on one hand, empathy seems to be *intrinsic* to the engineering profession as a whole, as engineers commonly purport that their profession saves and/or better peoples' lives and society

as a whole,75 which requires understanding the perspective and needs of the ones being served. On another hand, empathy seems to be the means to attain personal goals such as becoming better in teamwork, communication, management, client relationships, and leadership. Both of these perspectives are not mutually exclusive, yet may generate tensions and/or conflicts for the individual and the professional relationships the individual is involved in.

A similar tension arises with the question on the role of empathy as being a core part of engineering versus an add-on, in which our study echoes the sentiments of empathy being *core* as described by Walther and Kellam.[76] Most of our participating engineering faculty explored mechanisms whereby empathy and care indirectly exist in engineering already, whereas fewer pointed to an already overcrowded curriculum, suggesting these constructs were perhaps an unnecessary addition. With practicing engineers we see less presence of these tensions with a more utilitarian stance towards the constructs, the assumption seeming to be that the greater the amount of benefits possible from helping students cultivate these dispositions, the more important empathy and care becomes.

Outside of engineering, in disciplines such as nursing and psychology, the conceptualization of empathy is incomplete, although these disciplines have made concerted efforts at fostering the term in coherent and meaningful frameworks.77 When we situate empathy and care within engineering, the notions may look similar to the other fields' conceptualizations, but the terms may also look very differently. For example, when grander applications of empathy and care are discussed within engineering, the context is expanded. Rather than being individual–individual oriented, it may become individual–society oriented. In this engineering context, the individual clients may become removed from the situation.

This study shows the complexity of these phenomena as vivid when examining the wide array of findings. We feel comfortable emphasizing that the engineers we interacted with suggest empathy and care have the most value to engineers working in managerial or leadership roles. Nonetheless, all engineers work in teams and with different stakeholders, and understanding others involves coherent communication and perspective taking amongst team members.

Our findings include direct and indirect recommendations for the practice of educating engineers. While not explicitly stated within existing student outcomes, we argue that empathy and care are underlying constructs that, if not well addressed, lead to a misunderstanding or lacking support structure for attaining direct outcomes targeting relationship, communication, or responsibility-related criteria. Specific outcomes which strongly relate to empathy and care include helping engineers realize their ethical, social, and professional responsibilities, listening and communicating effectively, thinking holistically, and developing solutions in an ever-more globalized world. While developing empathy may help an individual become more *skilled* in areas such as teamwork, communication, management, client relationships, and leadership, our research indicates that the quality of the technical work is perceived to increase as well. Our research would further encourage engineering educators to find novel ways of incorporating

empathy and care into the teaching of more technical outcomes in order to overcome the unfounded dichotomy between technical and process (or soft) skills. Teaching might incorporate, for example, an increased focus on active listening skills and developing students' deep skills to fully incorporate clients' needs. Furthermore, a more holistic engineering profession which welcomes explicit recognition and promotion of empathy and care might provide a vehicle to attract different students to the field of engineering, increase the likelihood that broader audiences perceive engineering as a relevant, inclusive, and impactful profession, and so increase and retain diversity within the student body.

Limitations

Our research provides a preliminary insight into how empathy and care are conceptualized within engineering from the perspectives of existing literature, engineering faculty, and trained engineers. While our research provides new insights on the practice of engineering and necessary skills and attitudes, we have not focused on what potential benefits are most important when it comes to teaching empathy and care to engineers. Furthermore, we have not focused our attention on how such a pedagogy may be brought to the engineering education, nor what ABET-defined outcomes will *most* benefit from an inclusion of empathy or care. We were also limited by the minimal body of literature in engineering pertaining to empathy/care, our small number of faculty participating in the interviews, and the short nature of the statements from practicing engineers. In future work, our team will gather deeper perspectives from more participants, specifically practicing engineers, regarding the presence and importance of empathy and/or care to their professional careers and will verify findings with larger scale research utilizing survey instruments.

Acknowledgements

This study was made possible by the *Engineer of 2020 seed grant* from the College of Engineering at Purdue University entitled 'Pilot Study: Creating a Concerned Engineer in a Changing Environment'. 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 funding body. We would like to thank Jessica Sprowl, Melissa Dyehouse, and Nicole Weber for their valuable input during the research process and the participating faculty and engineering alumni/ae of Purdue Engineering for their thought-provoking comments and tolerance for our questions.

Notes

[1]Iacoboni, *Mirroring People*.

[2]Decety, *The Social Neuroscience of Empathy*.

[3]Baron-Cohen, *The Science of Evil*, 157.

[4]Zoltowski et al., “Students’Ways of Experiencing Human-Centered Design”.

[5]Walther, Miller and Kellam, “Exploring the Role of Empathy in Engineering Coummunication”.

[6]Grasso and Burkins, *Holistic Engineering Education*; Litzinger et al., “Engineering Education and the Development of Expertise”.

[7]Splitt, “The Challenge to Change”.

[8]National Research Council, *The Engineer of 2020*.

[9]National Research Council, *Educating the Engineer of 2020*, 10.

[10]Ibid., 152.

[11]National Research Council, *The Engineer of 2020*, 56.

[12]Ibid., 55.

[13]National Research Council, *Educating the Engineer of 2020*, 10.

[14]Davis, “Measuring Individual Differences in Empathy,” 113.

[15]Preston and de Waal, “Empathy”; Gerdes and Segal, “Importance of Empathy for Social Work Practice”.

[16]Berger, *Clinical Empathy*.

[17]Hojat et al., “Physician Empathy,” 1563.

[18]Kunyk and Olson, “Clarification of Conceptualizations of Empathy,” 318.

[19]deWaal, *The Age of Empathy*, 43.

[20]Iacoboni, *Mirroring People*.

[21]Chartrand and Bargh, “The Chameleon Effect”.

[22]Lakin et al., “The Chameleon Effect as Social Glue”.

[23]Ibid.

[24]Preston and deWaal, *Empathy*, 5f.

[25]Mayeroff, *On Caring*, 53.

[26]Moss, *The Emotionally Intelligent Nurse Leader*.

[27]Kunyk and Olson, “Clarification of Conceptualizations of Empathy,” 322.

[28]Berenguer, “The Effect of Empathy in Proenvironmental Attitudes and Behaviors”.

[29]Adams et al., “Multiple Perspectives on Engaging Future Engineers”.

[30]Adams and Felder, “Reframing Professional Development,” 239.

[31]Lathem, Neumann and Hayden, “Socially Responsible Engineer”; National Research Council, *The Engineer of 2020*.

[32]Grasso and Burkins, *Holistic Engineering Education*, 66.

[33]Sheppard et al., “Educating Engineers,” 4.

[34]Strobel et al., “Engineering as a Caring and Empathetic Discipline”.

[35]Hess et al., “Empathy and Caring as Conceptualized inside and Outside of Engineering”.

[36]Hsieh and Shannon, “Three Approaches to Qualitative Content Analysis”.

[37]Hill, *Consensual Qualitative Research*.

[38]Strobel et al., “Engineering as a Caring and Empathetic Discipline”.

[39]Hsieh and Shannon, “Three Approaches to Qualitative Content Analysis,” 1283.

[40]Leydens and Lucena, “The Problem of Knowledge in Incorporating Humanitarian Ethics,” T2H-24.

[41]Burnham, “The ‘Systems Approach’ to Human Problems,” 2.

[42]Campbell andWilson, “The Unique Value of Humanitarian Engineering,” 1.

[43]Haselkorn andWalton, “The Role of Information and Communication,” 325.

[44]Asgill, “Introducing Safety and Health Issues”; Hyndman, “A Thirty-Two Year Perspective on a Clinical Engineer’s Contributions to Patient Safety”.

[45]Ammerman, Sen and Stewart, “The Importance of Electrical Safety Training”.

[46]Bellamy, John and Kogan, “Deploying Cogtool”.

[47]Ramesh et al., “Can Distributed Software Development Be Agile?”.

[48]Morell de Ramirez et al., “Developing and Assessing Teamwork Skills in a Multi-Disciplinary Course,” 2.

[49]Brown, Flick, andWilliamson, “Social Capital in Engineering Education”.

[50]Derro and Williams, “Behavioral Competencies of Highly Regarded Systems Engineers at NASA,” 5.

[51]Ibid., 11.

[52]Siemieniuch and Sinclair, “They Fought Like Cats and Dogs …”, 786f.

[53]Barke, O’Neil Lane, and Knoespel, “Shaping the Future of American University Education”; Simrall, “IfYou Are a Concerned Engineer”.

[54]Saviz, “Service Learning Opportunity”.

[55]Nieusma and Riley, “Designs on Development”.

[56]Fleischmann, “Needed: A Few Good Knights for the Information Age,” S1B-8.

[57]Moriarty and Julliard, “On Subjectivity in Focal Engineering,” 182f.

[58]Burker, Paor, and Coyle, “Disability and Technology,” 56.

[59]Hovmark and Nordqvist, “Project Organization,” 393.

[60]Unger, ”Responsibility in Engineering,” 7.

[61]Lynn, “Cultural Differences and the Management of Engineering in Us-Japanese Joint Ventures,” 474.

[62]Wang, “Green Design and Humanized Design,” 2.

[63]Ibid., 1.

[64]Yong and Shan, “Intelligent Maintenance System”.

[65]Jian et al., “Collaborative Humanized Design,” 1079.

[66]Guo et al., “The Humanized Design of Children Furniture,” 517.

[67]Barke, Lane, and Knoespel, “Shaping the Future of American University Education”; Simrall, “If You Are a Concerned Engineer”.

[68]Saviz, “Service Learning Opportunity”.

[69]Nieusma and Riley, “Designs on Development”.

[70]Creswell, *Qualitative Inquiry & Research Design*, 199.

[71]McMillan and Schumacher, *Research in Education*, 5th. ed.

[72]Braun and Clarke, “Using Thematic Analysis in Psychology,” 6.

[73]Conceptualizations of these constructs in fields such as nursing and psychology are similarly complex, despite concerted efforts to develop cohesion, according to Kunyk and Olson, "Clarification of Conceptualizations of Empathy".

[74]Kunyk and Olson, "Clarification of Conceptualizations of Empathy," 138.

[75]Downey, "The Local Engineer".

[76]Walther, Miller, and Kellam, "Exploring the Role of Empathy in Engineering Coummunication".

[77]Kunyk and Olson, "Clarification of Conceptualizations of Empathy".

References

Adams, Robin, Demetra Evangelou, Lyn English,Antonio Dias De Figueiredo, Nicholas Mousoulides, Alice L. Pawley, Carmen Schiefellite, Reed Stevens, Marilla Svinicki, Julie Martin Trenor, and Denise M. Wilson. "Multiple Perspectives on Engaging Future Engineers." *Journal of Engineering Education* 100, no. 1 (2011): 48–88.

Adams, Robin, and Richard M. Felder. "Reframing Professional Development: A Systems Approach to Preparing Engineering Educators to Educate Tomorrow's Engineers." *Journal of Engineering Education* 97, no. 3 (2008): 239–40.

Ammerman, Ravel, Pankaj Sen, and Michael Stewart. "The Importance of Electrical Safety Training in Undergraduate Power Engineering Education." Paper presented at the American Society for Engineering Education Annual Conference, Chicago, IL, 2006.

Asgill, Austin. "Introducing Safety and Health Issues into an Engineering Technology Curriculum." Paper presented at the ASEE Annual Conference, Honolulu, HI, 2007.

Barke, Richard, Eliesh O'Neil Lane, and Kenneth Knoespel. "Shaping the Future of American University Education: Conceiving Engineering as a Liberal Art." Paper presented at the International Symposium on Technology and Society, Stamford, CT, 2001.

Baron-Cohen, Simon. *The Science of Evil: On Empathy and the Origins of Cruelty*. NewYork: Basic Books, 2011.

Bellamy, Rachel, Bonnie John, and Sandra Kogan. "Deploying Cogtool: Integrating Quantitative Usability Assessment into Real-World Software Development." Paper presented at the 33rd International Conference on Software Engineering, Honolulu, HI, 2011.

Berenguer, Jaime. "The Effect of Empathy in Proenvironmental Attitudes and Behaviors." *Environment and Behavior* 39 (2007): 269–83.

Berger, David M. *Clinical Empathy.* Northvale, NJ: Jason Aronson, 1987.

Braun,Virginia, andVictoria Clarke. “Using Thematic Analysis in Psychology.” *Qualitative Research in Psychology* 3, no. 2 (2006): 77–101.

Brown, Shane, Larry Flick, and Ken Williamson. “Social Capital in Engineering Education.” Paper presented at the 35th American Society for Engineering Education/Institute of Electrical and Electronics Engineers Frontiers in Education Conference, Indianapolis, IN, 2005.

Burker, Ted, Annraoi De Paor, and Eugene Coyle. “Disability and Technology: Engineering a More Equitable Ireland.” *Institute of Electrical and Electronics Engineers Technology and Society Magazine* 29, no. 1 (2010): 35–41.

Burnham, Matthew G. “The ‘SystemsApproach’to Human Problems:HowHumanitarian Engineering Can Help.” Paper presented at the Institute of Electrical and Electronics Engineeers International Symposium on Technology and Society, Tempe, AZ, 2009.

Campbell, Ryan C., and Denise Wilson. “The Unique Value of Humanitarian Engineering.” Paper presented at the American Society for Engineering Education Annual Conference, Vancouver, BC, Canada, 2011.

Chartrand, Tanya L., and John A. Bargh. “The Chameleon Effect: The Perception-Behavior Link and Social Interaction.” *Journal of Personality and Social Psychology*76, no. 6 (1999): 893–910.

Creswell, John W. *Qualitative Inquiry & Research Design: Choosing among Five Approaches*, 3rd ed. Thousand Oaks, CA: Sage Publications, 2013.

Davis, Mark H. “Measuring Individual Differences in Empathy: Evidence for a Multidimensional Approach.” *Journal of Personality and Social Psychology* 44, no. 1 (1983): 113–26.

Decety, Jean. *The Social Neuroscience of Empathy*. Cambridge, MA: MIT Press, 2009.

Derro, Mary Ellen, and Christine R.Williams. “Behavioral Competencies of Highly Regarded Systems Engineers at NASA.” Paper presented at the Institue for Eletrical and Electronic Engineers Aerospace Conference, Big Sky, MT, 2009.

Downey, Gary Lee. “The Local Engineer: Normative Holism in Engineering Formation.” In Engineering, Development and Philosophy, eds. Steen Hyldgaard Christensen, Carl Mitcham, Bocong Li, andYanming An, 233–51. Springer, 2012.

Fleischmann, Shirley T. “Needed: A Few Good Knights for the Information Age – Competence, Courage, and Compassion in the Engineering Curriculum.” Paper presented at the 31st American Society for Engineering Education/Institute of Electrical and Electronic Engineers Frontiers in Education Conference, Reno, NV, 2001.

Gerdes, Karen E., and Elizabeth Segal. “Importance of Empathy for SocialWork Practice: Integrating New Science.” *Social Work* 56, no. 2 (2011): 141–48.

Grasso, Domenico, and Melody Brown Burkins. *Holistic Engineering Education: Beyond Technology*. NewYork, NY: Springer, 2010.

Guo, Xiaoyan, Yuhua Cao, Dehui Ye, and Yaohui Guo. “The Humanized Design of Children Furniture.” Paper presented at the Institute of Electrical and Electronic Engineering 11th International Conference on Computer-Aided Industrial Design & Conceptual Design,Yiwu, China, 2010.

Haselkorn, Mark, and RebeccaWalton. “he Role of Information and Communication in the Context of Humanitarian Service.” *IEEE Transactions on Professional Communication* 52, no. 4 (2009): 325–28.

Hess, Justin L., Jessica Erin Sprowl, Rui Pan, Melissa Dyehouse, Carrie A. Wachter Morris, and Johannes Strobel. “Empathy and Caring as Conceptualized inside and Outside of Engineering:

Extensive Literature Review and Faculty Focus Group Analyses.” Paper presented at the American Society for Engineering Education Annual Conference & Exposition, San Antonio, TX, 2012.

Hill, Clara E., ed. *Consensual Qualitative Research: A Practical Resource for Investigating Social Science Phenomena*. Washington, DC: American Psychological Association, 2012.

Hojat, Mohammadreza, Joseph S. Gonnella, Thomas J. Nasca, Salvatore Mangione, Michael Vergare, and Michael Magee. “Physician Empathy: Defintion, Components, Measurement, and Relationship to Gender and Specialty.” *American Journal of Psychiatry* 159, no. 9 (2002): 1563–69.

Hovmark, Svante, and Stefan Nordqvist. “Project Organization: Change in theWork Atmosphere for Engineers.” *International Journal of Industrial Ergonomics* 17, no. 5 (1996): 389–98.

Hsieh, Hsiu-Fang, and Sarah E. Shannon. “Three Approaches to Qualitative Content Analysis.” *Qualitative Health Research* 15, no. 9 (2005): 1277–88.

Hyndman, Bruce H. “AThirty-TwoYear Perspective on a Clinical Engineer’s Contributions to Patient Safety.” Paper presented at the Annual international conference of the Institute of Electrical and Electronic Engineers Engineering in Medicine and Biology Society, San Fransico, CA, 2004.

Iacoboni, Marco. *Mirroring People: The Science of Empathy and HowWe Connect with Others*. New York: Picador, 2009.

Jian, Zhang, Shang Xiuwei,Yu Xuebin, Li Li, and Zhao Fang. “Collaborative Humanized Design of NCMachineTools.” Paper presented at the Institute of Electrical and Electronic Engineering 10th International Conference on Computer-Aided Industrial Design&Conceptual Design,Wenzhou, China, 2009.

Kunyk, Diane, and Joanne K. Olson. “Clarification of Conceptualizations of Empathy.” *Journal of Advanced Nursing* 35, no. 3 (2001): 317–25.

Lakin, Jessica L.,Valerie E. Jefferis, Clara Michelle Cheng, and Tanya L. Chartrand. “The Chameleon Effect as Social Glue: Evidence for the Evolutionary Significance of Nonconscious Mimicry.” *Journal of Nonverbal Behavior* 27, no. 3 (2003): 145–62.

Lathem, SandraA., Mareen D. Neumann, and Nancy Hayden. “Socially Responsible Engineer:Assessing Student Attitudes of Roles and Responsibilities.” *Journal of Engineering Education* 100, no. 3 (2011): 444–74.

Leydens, Jon A., and Juan C. Lucena. “The Problem of Knowledge in Incorporating Humanitarian Ethics in Engineering Education: Barriers and Opportunities.” Paper presented at the 36thAnnual Frontiers in Education Conference, San Diego, CA, 2006.

Litzinger, Thomas, Lisa R. Lattuca, Roger Hadgraft, andWendy Newstetter. “Engineering Education and the Development of Expertise.” *Journal of Engineering Education* 100, no. 1 (2011): 123–50.

Lynn, Leonard H. “Cultural Differences and the Management of Engineering in Us-Japanese JointVentures.” Paper presented at the Conference on Technology Management: The New International Language, Portland, OR, 1991.

Mayeroff, Milton. *On Caring*. NewYork, NY: Harper and Row, 1971.

McMillan, James, and Sally Schumacher. *Research in Education: A Conceptual Introduction*, 5th ed. NewYork: Longman, 2001.

Morell de Ramirez, Lueny, Jorge I. Vélez-Arochio, José L. Zayas-Castro, and Miguel A. Torres. “Developing and Assessing Teamwork Skills in a Multi-Disciplinary Course.” Paper presented at the Frontiers in Education, Tempe, AZ, 1998.

Moriarty, Gene, and Y. Julliard. “On Subjectivity in Focal Engineering.” Paper presented at the International Symposium on Technology and Society, Stamford, CT, 2001.

Moss, Mae Taylor. *The Emotionally Intelligent Nurse Leader*, Vol. 20. Jossey-Bass, 2004.

National Research Council. *The Engineer of 2020: Visions of Engineering in the New Century*. Washington, DC: National Academies Press, 2004.

National Research Council. *Educating the Engineer of 2020: Adapting Engineering Education to the New Century*. Washington, DC: National Academies Press, 2005.

Nieusma, Dean, and Donna Riley. “Designs on Development: Engineering, Globalization, and Social Justice.” *Engineering Studies* 2, no. 1 (2010): 29–59.

Preston, Stephanie D., and Frans B. M. de Waal. “Empathy: Its Ultimate and Proximate Bases.” *Behavioral and Brain Sciences* 25, no. 1 (2002): 1–20.

Ramesh, Balasubramaniam, Lan Cao, Kannan Mohan, and Peng Xu. “Can Distributed Software Development Be Agile?” *Communications of the Association for Computing Machinery* 49, no. 10 (2006): 41–6.

Saviz, Camilla M. “Service Learning Opportunity:A University and Community Partnership in Creek Restoration.” Paper presented at the 34th American Society for Engineering Education/Institute for Electrical and Electronics Engineers Frontiers in Education Conference, Savannah, GA, 2004.

Sheppard, Sheri D., Kelly Macatangy, Anne Colby, and William M. Sullivan. Educating Engineers: Designing for the Future of the Field. San Francisco, CA: Jossey-Bass, 2009.

Siemieniuch, Carys E., and MurrayA. Sinclair. “They Fought Like Cats and Dogs ….” Paper presented at the Institute of Electrical and Electronic Engineering International Engineering Management Conference, Cambridge, UK, 2002.

Simrall, Harry C. “IfYou Are a Concerned Engineer.” *IEEE Spectrum* 8, no. 2 (1971): 69–71.

Splitt, Frank G. “The Challenge to Change: On Realizing the New Paradigm for Engineering Education.” *Journal of Engineering Education* 92, no. 2 (2003): 181–87.

Strobel, Johannes, Carrie Wachter Morris, Lisa Klingler, Rui Pan, Melissa Dyehouse, and Nicole Weber. “Engineering as a Caring and Empathetic Discipline: Conceptualizations and Comparisons.” Paper presented at the Research in Engineering Education Symposium, Madrid, Spain, 2011.

Unger, Stephen H. “Responsibility in Engineering: Victor Paschkis Vs. Wernher Von Braun.” *IT Professional* 12, no. 3 (2010): 6–7. de Waal, Frans. *The Age of Empathy: Nature’s Lessons for a Kinder Society*. New York: Harmony Books, 2009.

Walther, Joachim, Shari E. Miller, and Nadia N. Kellam. “Exploring the Role of Empathy in Engineering Coummunication through a Trans-Disciplinary Dialogue.” Paper presented at the American Society for Engineering Education Annual Conference, San Antonio, TX, 2012.

Wang, Zhiyong. “Green Design and Humanized Design in High Speed Train’s Industrial Design Management.” Paper presented at the International Conference on Management and Service Science,Wuhan, China, 2011.

Yong, Yang, and Wen Shan. “Intelligent Maintenance System for Construction Machinery Based on Collaborative Kansei Engineering.” Paper presented at the International Conference on Computational Intelligence and Software Engineering,Wuhan, China, 2009.

Zoltowski, Carla B., William C. Oakes, and Monica E. Cardella. “Students’Ways of Experiencing Human-Centered Design.” *Journal of Engineering Education* 101, no. 1 (2012): 28–59.