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A MULTI-PHASE EXPLORATION OF CONCEPTUALIZATIONS,

PERCEIVED IMPORTANCE, AND THE DEVELOPMENT OF EMPATHY

WITHIN ENGINEERING

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To my father, who taught me to always question

To my mother, who taught me to always laugh

To my grandmother, who taught me to always care

To my partner, who taught me to always love

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# ABSTRACT

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Throughout the United States, there have been numerous calls for the development of well-rounded engineers through a more holistic engineering education. This dissertation is a collection of three independent but related studies exploring the role of a disposition that seems intimately connected to many skills described as necessary for the next generation of engineers within these calls: empathy. Each chapter of this dissertation provides unique insights on conceptualizations, perceptions of the importance, and the development of this phenomenon within engineering and engineering education.

The first study investigates how empathy and care look within an engineering context through three separate but interrelated phases including (a) a summative content analysis of existing literature, (b) thematic analysis of small group interviews with engineering faculty, and (c) thematic analysis of written responses from practicing engineers to an open-ended question about empathy and care. Taken together, findings from these three phases demonstrate that although empathy and care have a place within

engineering, conversations and awareness of these phenomena are not often explicitly stated within the literature or frequently addressed by engineers or engineering faculty.

The second study explores the importance and existence of empathy and care within engineering practice. This study includes (a) thematic analysis of engineers' conceptualizations of empathy and care (n = 25), (b) phenomenological analysis of engineers' experiences of empathy and care within the workplace (n = 25), (c) exploratory factor analysis of an empathy and care survey (n = 1574), and (d) non-parametric testing of engineers' responses to the derived factor structure (n = 1481) to explore in what ways empathy and care are perceived as most important to engineering practice, and whether these perceptions vary by gender or years of work experience. Phenomenological analysis led to the emergence of 13 themes along four categories including (a) design outcomes, (b) personal outcomes, (c) relational outcomes, and (d) broader ideas. Non-parametric testing of the derived factor structure indicated that practicing engineers with greater years of work experience were more likely to perceive empathy and care as existing in engineering practice and as important to their work.

The third study explores developments in undergraduate engineering students' perspective-taking tendencies after participating in an engineering ethics course. This study follows a concurrent mixed methodological research approach, first analyzing students' changes in a psychometric instrument (the Interpersonal Reactivity Index) along with evaluative changes in an ethics transfer case study, and second through thematic analysis of critical incidents derived from semi-structured interviews with course participants (n = 19). Quantitative findings indicated that students' self-reported perspective-taking tendencies increased over the course of the semester and qualitative findings indicated there were six fundamentally distinct causes of this increase and five distinct types of outcomes related to perspective-taking.

Taken together, the results from these three inter-related studies highlight contextual considerations for allowing empathy to manifest itself within engineering, potential pathways and improved outcomes of an empathically guided engineering process, and educational design strategies for prompting critical experiences to develop engineering students' empathic tendencies.

# CHAPTER I

# DISSERTATION OVERVIEW

# CHAPTER I. DISSERTATION OVERVIEW

## INTRODUCTION

This dissertation is a collection of three independent but related studies exploring the role of a disposition that seems intimately connected to many skills described as necessary for the next generation of engineers: empathy. A common contemporary idiom depicts empathy as putting one's self in another's shoes. This idiom suggests empathy is a simple act. However, a brief exploration of scholarly literature on empathy will quickly highlight the complexity of this nuanced phenomenon. While throughout this dissertation, this complexity will be unpacked, I begin with an operational definition of empathy so that the reader may begin to understand how I conceptualize this phenomenon.

For me, empathy is a non-linear process of considering and internalizing the perspective of another and the resulting outcome of accurately comprehending that other's thoughts, emotions, and state of being. Empathy is both experiential (e.g. experiencing how another is feeling) and cognitive (e.g. understanding how another is thinking and feeling). It is a 'neutral' phenomenon, meaning it does not require sympathy (feeling an emotion for another, such as pity), judgment (agreeing or disagreeing with another), or action (although it may induce helping behavior). Scholars sometimes use distinct constructs to conceptualize or frame empathy, such as emotional congruence or perspective-taking. While these constructs are distinct, they may operate in unison so that an empathizer may holistically understand another.

A focus on empathic design emerged less than twenty years ago (Leonard & Rayport, 1997; Mattelmäki, Vaajakallio, & Koskinen, 2014; Postma, Zwartkruis-Pelgrim, Daemen, & Du, 2012) and a focus on empathy within engineering has slowly emerged in that time. Prior to 2011, explicit uses of empathy within engineering literature were rare. Strobel et al. (2011) found only 22 peer-reviewed articles published after 1980 within engineering literature which explicitly used the term empathy in some form. These authors grouped the found literature into (a) engineering education, (b) engineering management, (c) engineering ethics, and (d) engineering professional development. My follow-up cursory analysis of these publications suggested that empathy was only the core focus of one of these articles (see Vallero & Vesilind, 2006) and was only a subsidiary point of emphasis in all others, as evident by its limited usage. Nine of the 22 articles used the term once, 19 articles used the term six times or less, and only four of the articles offered some definition of what they meant by the term. This suggests that a concerted discourse focusing on the role of empathy within engineering is lacking. I theorize that this lack is not due to the unimportance of this phenomenon, but rather a lacking conceptual foundation for applying the phenomenon within engineering.

## CONCEPTUAL FRAMEWORK

While a singular conceptual foundation for applying empathy within engineering does not yet exist, this is not to say that engineering is entirely unique from other disciplinary realms in this respect. As Kunyk and Olson (2001) note, there is no consensus throughout scholarly nursing literature on exactly what empathy means. If nursing has been using the term for more than 60 years (e.g. see Peplau 1952) and this trend prevails in nursing literature today, then it seems that engineering scholars focusing on this phenomenon will have some catching up to do. An examination of Decety and Ickes' (2009) edited book, *The Social Neuroscience of Empathy*, shows that distinguished empathy researchers vary widely in their conceptualization of the phenomenon, as evident by chapter-by-chapter variations in this collection.

Part of the difficulty in conceptualizing this emergent concept, as Gompertz (1960) noted long ago, is that research around empathy is related to a plethora of synonyms, such as role-playing, insight, and perception of reality. The trend persists today, as empathy is commonly divided into two or three primary (but not necessarily mutually exclusive) components: (a) knowing, (b) feeling, and (c) responding compassionately (Levenson & Ruef, 1992). Lawrence et al. (2006) distinguish between "cognitive" and "affective" empathy, where the cognitive aspect involves "understanding and predicting someone else's mental state" and the affective aspect involves "experiencing an emotion as the result of someone else's mental state" (p. 1173).

Batson (2009), in the opening chapter of Decety and Ickes' (2009) *Social Neuroscience of Empathy*, suggests that there exist eight common conceptualizations of empathy: (a) **Knowing** another person's internal state, including his or her thoughts and feelings, (b) **Adopting** the posture or matching the neural responses of an observed other, (c) Coming to **feel as another** person feels, (d) Intuiting or **projecting** one's self into another's situation, (e) **Imagining how another** is thinking and feeling, (f)

**Imagining how one** would think and feel in another's place, (g) **Feeling distress at witnessing another** person's suffering, and (h) **Feeling for another** person who is suffering. Most of these conceptualizations span across the cognitive and affective domains and a few include behavioral outcomes. This seems to suggest that action is not core to empathy, but rather, a possible result of empathizing for or with another. M. H. Davis (1996) considers action, or helping behavior, an empathic *outcome*.

An equally important focus in the chapters of this dissertation is on the role of "care" in engineering practices. Scholars commonly conceptualize care in relation to or as an extension of empathy, although as Strobel et al. (2011) noted, "There is no relationship in the literature regarding the relationship between empathy and caring" (p. 2). Some authors support the notion that empathy generates an understanding, which in turn leads to actions in the form caring (Batson, 1990; Sutherland, 1993). For example, Hatfield et al. (2009) explains, "[T]rue empathy requires three distinct skills: the ability to share the other person's feelings, the cognitive ability to intuit what another person is feeling, and a 'socially beneficial' intention to respond compassionately" (p. 19). Even this conceptualization suggests empathy does not necessarily result in action, but rather good-willed intention.

The operational framing I will adopt (which is informed by the studies presented throughout this dissertation) is that empathy tends to lead to caring, but caring does not necessarily require empathy. Empathy in its purest form leads to an understanding of another, which may require 'experiencing' the other at least to a minimal extent, whereas caring may be the action resulting from a possible extension of this understanding. When taken together, empathy and care involve both understanding another and acting on another's behalf. That is to say that empathy and care involve empathically accurate responses intended to help others. My primary exploration throughout this dissertation is on empathy, although this noted relationship between empathy and care permeates much of the discourse that follows.

While each of the chapters of this dissertation give voice to the participants, Chapters 2 and 3 seek to understand how the participants define empathy and care themselves. In these processes, the goal is not to be (mis)guided by my a priori conceptualizations. Yet, to reiterate, the studies contained within (Chapters 2-5) deeply influenced understanding of these constructs at the time of this writing.

## EMPATHY AND ENGINEERING

Promoting empathy within engineering may have many benefits, such as promoting the individual engineer's ability to anticipate and resolve interpersonal problems (Baron-Cohen, 2011), to understand the needs of users (Hey, Van Pelt, Agogino, & Beckman, 2007; Leonard & Rayport, 1997), to become intrinsically motivated to act altruistically (Batson, Ahmad, & Lishner, 2011; Eisenberg & Miller, 1987), or to enhance an engineer's ethical decision-making skills (Hoffman, 2000; Oxley, 2011; Vallero, 2008). Nonetheless, within engineering literature, explicit attention on empathy has been minimal, as shown in the recent pilot literature review research study by Strobel et al. (2011) mentioned already.

Still, in the past few years researchers have explicitly began using the term empathy within the domain of engineering education. Zoltowski, Oakes, and Cardella

(2012) identified “empathic design” as the most “comprehensive category” of “human-centered design”. Walther, Miller, and Kellam (2012) suggested empathy was a “core aspect of engineering communication” and have already worked towards including empathy within undergraduate engineering courses. Jordan, Lande, Cardella, and Ali (2013) implemented an alien-centered design effort within engineering courses with the goal being to foster engineering design students’ empathy towards fictitious users. Likewise, D. G. Johnson et al. (2014) explored the influence of ‘empathic experiences’ (students attempted to experience what it was like to ‘be’ a user with lessened sensory capacities) on engineering students’ designs. Lastly, Lynch et al. (2014) found one of the key student outcomes in a service-learning course where students designed for elderly patients was a more empathic disposition towards that user group.

My exploration of empathy has already taken me down tangential paths, all of which are not directly included within this dissertation. These studies have included a focus on the role of empathy in ethical decision-making within engineering (Hess et al., 2014; Hess, Beever, Strobel, & Brightman, under review), the relationship between empathy and innovation (Hess, Fila, Strobel, & Purzer, 2015), how empathy may improve design for assistive-technologies (Jaycox, Hess, Zoltowski, & Brightman, 2014), and how empathy manifests itself throughout a service-learning design process (Fila & Hess, 2014).

Taken together, the growing emphasis on empathy within design and engineering supports the notion that empathy may have a multiplicity of positive outcomes if implemented within engineering curricula. Given the potential importance and growing interest in empathy within engineering practice and engineering education, there is a needed conceptual basis to apply the term throughout these domains.

## CHAPTER OVERVIEW

This dissertation seeks to provide a foundation for engineers and engineering educators to incorporate empathy into their work and classroom. The overall research purpose falls broadly into three categories:

1. To develop a conceptual understanding of empathy within engineering
2. To explore the importance and value of empathy within the practice of engineering
3. To understand mechanisms by which engineering students may become more empathic

I approach each of these objectives with a distinct methodological framework and distinct research questions along each chapter. The second chapter explores conceptualizations of empathy and care and their importance within engineering through three phases: (a) an extensive literature review, (b) small-group interviews with engineering faculty, and (c) written responses from practicing engineers. The third chapter is an extension of the second, but here the focus is on how practicing engineers conceptualize empathy and experience it within their work. The fourth chapter slightly diverges from the second and third, as here the focus is on students' development of empathic perspective-taking tendencies as a result of participating in a course on engineering ethics. The fifth and final chapter aims to integrate findings from each of the preceding chapters, addressing the overall three research objectives, and providing an overview for future extensions of this research. Figure 1.1. depicts Chapters 2-4 taxonomically.

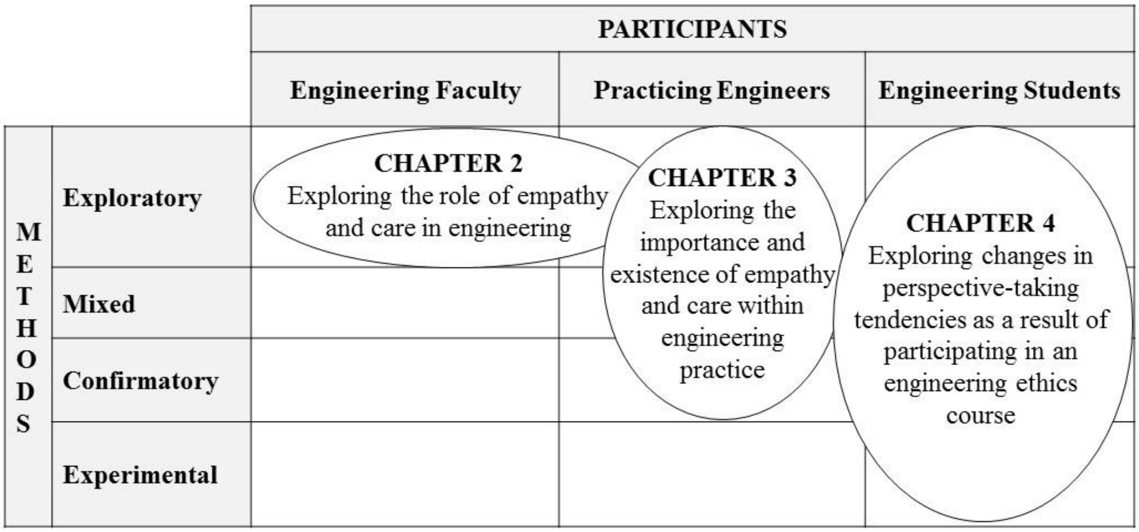


**Figure 1.1**: *Chapter taxonomy, compared by methods used and participants sampled*

As Figure 1.1 shows, in Chapter 2 the participants include engineering faculty and practicing engineers. This chapter is solely exploratory and follows a multi-phase design. Chapter 3's participants are practicing engineers and here we implement a mixed methods approach. Similarly, Chapter 4's participants are engineering students (some of whom are also practitioners). This fourth chapter expands all categories depicted in Figure 1.1 for the context or "experimental intervention" is an engineering ethics course. I provide a brief overview of each chapter in the following sub-sections.

**Chapter 2: A Multi-Phase Exploration**

Chapter 2 follows a multi-phase research approach and includes three sequential qualitative phases exploring the role of empathy and care within engineering. The first phase explores the usage and conceptualizations of like-terms associated with empathy and care by implementing a summative content analysis of select peer-reviewed engineering literature. The second phase uses narrative views of engineering faculty collected from small-group interviews to understand how engineering faculty perceive empathy and care within engineering. The third phase is similar to the second, but here the analysis is on written perspectives of practicing engineers. These results help generate an emergent understanding of existing conceptualizations and deemed importance of empathy within engineering. Further, they provide a means of distinguishing empathy from care, and an avenue for understanding what may be contained within an engineering-specific construct that combines both empathy and care. These findings inform the development of the quantitative instrument used in Chapter 3.

**Chapter 3: Insights from Industry**

This third chapter focuses specifically on practicing engineers' perspectives of the role of empathy and care within engineering. This study follows a concurrent triangulation mixed methods research design. In the initial phase of this study, we thematically analyze semi-structured interviews with 25 practicing engineers are to further elucidate conceptualizations of empathy and care within an engineering context, alongside how practicing engineers consider empathy and care to be important to and existing within their work. In this sense, qualitative outcomes of this study include *conceptual* themes and *phenomenological* themes. The second phase of this study is quantitative, where we use exploratory factor analysis and non-parametric testing to explore nearly 1500 responses to a 37-item survey. The final phase integrates these findings to provide a holistic picture of the salience of empathy and care to the practice of engineering from the perspective of a diverse group of engineering practitioners.

## Chapter 4: The Development of Perspective-Taking Tendencies

Chapter 4 is an extension of Chapters 2 and 3 that focuses on a single empathy construct: empathic perspective-taking. This chapter explores developments in students' empathic perspective-taking tendencies as a result of participating in a multi-disciplinary engineering ethics course. This chapter, taken by itself, is the most dissertation-like. As in Chapter 3, this chapter uses a concurrent triangulation mixed methods research design, but here the quantitative section comes first. The quantitative comparative measures include pre-post testing of a psychometric instrument validated in the field of social psychology (see M. H. Davis 1980, 1983) and an Ethics Transfer Case methodology (see Hess et al. 2014). The qualitative component of this study uses Critical Incident Technique (Flanagan, 1954) to uncover the aspects of students' experiences that seem to have sparked changes in their perspective-taking tendencies, along with a thematic and narrative description of my interpretations of these themes. This chapter directly informs engineering curricula might develop engineering students' empathic tendencies (namely, perspective-taking) both within and beyond ethics course offerings.

## Chapter 5: A Summative Overview

The final chapter provides an overview of the results from each preceding chapter. It describes (a) how empathy may be **framed** within an engineering context as compared to traditional contexts where empathy is already commonly used, (b) potential engineering **outcomes** when empathy guides the engineering process, (c) **context-**

considerations for embedding empathy within engineering practice or institutions, (d) the **scope** of empathy within an engineering context, (e) the relevance of alleviating empathic **biases** when considering empathy in engineering, and (f) **developmental** considerations for situating empathy within engineering curriculum. I use these considerations to map broader implications for engineering educators, along with future research spaces for exploring the role of empathy in engineering.

# CHAPTER II

## A MULTI-PHASE EXPLORATION: PERSPECTIVES FROM ENGINEERING LITERATURE, FACULTY, AND PRACTITIONERS

Hess, J. L.*, Strobel, J.*, Pan, R. C., & Wachter Morris, C. A. (2013). Empathy and Care Within Engineering: Qualitative Perspectives from Engineering Faculty and Practicing Engineers. *Engineering Studies, 5*(3).

**Denotes equal authorship*

# CHAPTER II. A MULTI-PHASE EXPLORATION

## ABSTRACT

The purpose of this study is 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 employs three separate, but interrelated studies, including a summative content analysis of existing literature, consensual qualitative research analysis of small group interviews with engineering faculty, and 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 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. This study's analysis and interpretation regarding how these findings parallels and departs from existing conceptualizations of empathy and care is specified, and implications for engineers and the practice of engineering in general is discussed.

# INTRODUCTION

This paper explores how empathy and care look within an engineering context by analyzing related literature and investigating perspectives from engineering faculty and practicing engineers. Specifically, we explore the presence and conceptualizations of empathy and care in 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 ten 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" (Iacoboni, 2009) and "The Social Neuroscience of Empathy" (Decety & Ickes, 2009), 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 (2011) – until recently society and scientists have ignored its "*most valuable resource* in our world" (p. 157).

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 care is glaring. This comes as a surprise because *empathic design* has been considered as the most comprehensive form of human-centered design (Zoltowski, Oakes, & Cardella, 2012) and *empathic communication skills* may enable engineers to develop personal connections with users and stakeholders (Walther, Miller, & Kellam, 2012; Leydens & Lucena, 2006). 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 (Grasso & Burkins, 2010; Litzinger, Lattuca, Hadgraft, & Newstetter, 2011), the Renaissance engineer (Splitt, 2003), and the Engineer of 2020 (National Academy of Engineering, 2004; 2005). Many concepts introduced in these frameworks relate to empathy and care, although authors seldom use this specific terminology. An empathic and caring aptitude may be prerequisite to "[f]lexibility, receptiveness to change, and mutual respect" (National Academy of Engineering, 2005, p. 10), "respect for ways of life different from ours" (p. 152), and "high ethical standards" (2004, p. 56). 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" (p. 55) requires at least a minimum level of empathy. In essence, engineers need "well-developed people skills in addition to their ability to solve problems" (National Academy of Engineering, 2005, p. 10).

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 of 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 the research questions regarding how empathy and care show themselves within engineering.

The primary research objective throughout this multi-phase research study is to understand how empathy and care look when situated within an engineering context from multiple sources and perspectives, including (1) existing literature (2) engineering faculty and (3) practicing engineers. The following research questions guide this inquiry:

(1) How does existing engineering literature conceptualize and present empathy and care?

(2) How do engineering faculty members perceive empathy and care as related to engineering practice?

(3) How do practicing engineers perceive empathy and care perceived as related to engineering practice?

In the following sections we provide a background on how empathy and care are conceptualized in 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 embedding these phenomena in curriculum. 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) as compared to 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" (M. H. Davis, 1983, p. 113). Oftentimes, when defining empathy, authors describe a tension between its cognitive and emotive dimensions (Gerdes, Segal, & Lietz, 2010; Preston & de Waal, 2002). Cognitively, empathy is a process involving understanding the experience of others (Berger, 1987). Emotively, empathy is understood as “the capacity to enter into or join the experiences and feelings of another person” (Hojat et al., 2002, p. 1563). 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 (2001) 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” (p. 318). 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” (de Waal, 2009, p. 43) potentially evoking mimicry of another person’s behavior (Iacoboni, 2009), which in turn leads to enhanced interaction between individuals (Chartrand & Bargh, 1999) and/or the development of harmonious social relationships (Lakin, Jefferis, Cheng, & Chartrand, 2003). Without empathy, these interactions and relationships cannot be developed. Therefore, empathy may be necessary to the evolution and survival of social groups (Lakin et al., 2003).

Preston and de Wall (2002) suggest that at its “ultimate bases” empathy occurs through one’s “response-oriented nervous system” and is a “perception-action process” (p. 5f). The likelihood that human subjects will help another 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 performs a rational function crucial to decision-making processes.

Care is a similarly complex construct, involving both feelings and actions. It is a concept that dwells in intentions and actions of people who are pursuing the wellbeing 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" (Mayeroff, 1971, p. 53), an action which is intrinsically rewarding to the caring individual (Moss, 2005). If one cares about an object, no matter the interpreted results of a cost-benefit analysis, the likelihood that one will evoke helping behavior is higher than if one were not to care. The more we care, the more likely we are to take action. Thus, when Kunyk and Olson (2001) define "empathy as caring" they pair understanding "of the client's situation" with "a compulsion to act" (p. 322). 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 (2007) showed that an increase in empathy for another person or natural objects leads to an increase in willingness to actively help that person or the object (e.g. the environment).

Following the existing conceptualizations, in this 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 (Adams et al., 2011). 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" (Adams & Felder, 2008, p. 239). Specifically, future engineers need to develop specific character qualities, affective dispositions, and habits of mind (Lathem, Neumann, & Hayden, 2011; National Academy of Engineering, 2004). 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" (Grasso & Burkins, 2010, p. 66). Sheppard, Macatangay, Colby, and Sullivan (2008) 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. (p. 4)

**Previous Research**

In a pilot literature review, the 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 (Strobel et al., 2011). 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 faculty from helping fields were comfortable asserting that engineers *do not* base their work around empathic or caring considerations (Hess et al., 2012). These empathy/care experts suggested the public likely held similar stereotypes, although these participants believed a focus on empathy and care might ebb away such impersonal and gender (mis)conceptions (Hess et al., 2012).

# METHODOLOGY & INTERPRETIVE FINDINGS

The following research questions guided 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 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 2.1 we conduct a systematic literature review guided by summative content analysis (Hsieh & Shannon, 2005). In Phases 2.2 and 2.3 we employ consensual qualitative research (Hill, 2012). The specific data collection methods we use, corresponding to each phase, include: (1) Systematic literature review, (2) Small group interviews with engineering faculty, and (3) Open responses from practicing engineers. In all phases we employ thematic analysis (Braun & Clarke, 2006).

## Phase 2.1: Extensive Literature Review

Phase 2.1 is an extension of a previously conducted literature review that examined how empathy and care were explicitly presented within engineering literature (Strobel et al., 2011). During this current study, we explore research studies which contained key concepts and attributes of empathy and care, yet did not explicitly use the terms.

**Data collection.** By exploring the literature explicitly including empathy or care, we generated a keyword list of terms used frequently alongside these terms. These keywords included "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" (Hsieh & Shannon, 2005, p. 1283). After identifying articles that employed the aforementioned keywords, we next analyzed how these words were defined in these collected references. We opted to focus this exploration *only* on 46 of the 106 collected papers as in these papers variables and keywords around empathy and care were explicitly defined. Table 2.1 shows the number of papers we collected and analyzed paired to each keyword.

**Table 2.1:** *Summary of articles found from extensive literature review*

| Keywords | Papers collected | 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 |

**Phase 2.1 Findings**

Findings of this literature review suggested that empathy and care are rarely explicitly represented in engineering education literature, although associated terms are used more commonly. Specifically, the 8 keywords in Table 2.1 seem to embody implications of empathy and care while neglecting the use of the "empathy" and "care" 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.

**Humanitarian.** First, 27 articles addressed the category of humanitarian engineering. Humanitarian engineering is "the application of engineering knowledge and skills to communities in need" (Leydens & Lucena, 2006, pp. T2H-24). 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" (Burnham, 2009, p. 2). Constraints for humanitarian design may be "physical, economic, environmental, legal, political, cultural and ethical" (Campbell & Wilson, 2011, p. 1). In the editorial for the special issue on *The Role of Information and Communication in the Context of Humanitarian Service*, Haselkorn and Walton (2009) argued 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" (p. 325).

**Safety.** 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 (Asgill, 2007; Hyndman, 2004) and that engineers should focus attention towards preventing and addressing hazardous or injurious accidents which may occur as a result of their type of work (Ammerman, Sen, & Stewart, 2006). These conceptions of safety were commonly utilized in a managerial context or through discourse of liabilities.

**Building trust.** Third, building trust was mentioned in 13 of the collected articles. Trust was considered to be needed between engineers and customers (Bellamy, John, & Kogan, 2011), between different working groups (Ramesh, Cao, Mohan, & Xu, 2006), and was regarded as one of the "baseline non-technical skills for team members" (Morell de Ramirez, Vélez-Arocho, Zayas-Castro, & Torres, 1998, p. 2). Brown, Flick and Williamson (2005) suggested building trust was one of the important components of social capital that must be taught in engineering. Derro and Williams (2009) summarized competencies and associated behaviors of highly regarded systems engineers at NASA, which included respect, credibility, and trust. Derro and Williams saw "trust of self and others as a pervasive element required to achieve success" (p. 11). Behaviors which help individuals gain respect, credibility and trust include using a respectful tone, words and body language, following through on commitments, 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. Siemieniuch and Sinclair (2002) argued that the quality of trust depends on a number of things, including establishing common goals and being transparent about problems and ways of working (p. 786f).

**Users' needs.** Fourth, users' needs were discussed in 12 of the articles. This literature indicated that engineers should design products to satisfy users' need, and that what users need should be identified in the early stages of design (Barke, Lane, & Knoespel, 2001; Simrall, 1971). Various techniques, including interviews, scenarios, and questionnaires, have been described as methods to elicit such needs (Saviz, 2004). Similarly, empathic design has been described as the most comprehensive form of human-centered design (Zoltowski, Oakes, & Cardella, 2012) and engineers employing empathic design approaches focus their efforts towards 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 (Nieusma & Riley, 2010).

**Compassion.** Fifth, nine of the articles explicitly discussed compassion. Here the notion was that effective engineers must understand "how technical solutions will fit into context. This understanding requires a level of understanding and compassion for those who will benefit from engineering design activities" (Fleischmann, 2001, pp. S1B-8). Moriarty and Julliard (2001) 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" leads to ideal outcome (p. 182f). Burke, de Paor & Coyle (2010) 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" (p. 56).

**Solidarity.** Sixth, another nine articles discussed solidarity. Here the notion was that "teamwork and group solidarity are crucial for project success" (Hovmark & Nordqvist, 1996, p. 393). Unger (2010) suggested that lack of solidarity leaves engineers "exposed to career damage", and that solidarity may be grown through participation in a larger community beyond the employer (e.g. engineering organizations, professional societies, unions) (p. 7). Lynn (1991) 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 (p. 474).

**Humanized.** Seventh, nine articles discussed the concept of humanized engineering or design. In humanized design engineers take "physiological, psychological, behavioral and cultural factors" into account (Wang, 2011, p. 2). Humanized design originated from a focus "on the needs of human-being in modern age" (p. 1). Yong and Shan (2009) argued that a humanized system should be able to integrate the "Kansei characteristics of human[ity] such as affection, feelings, [and] emotions". Jian, Xiuwei, Xuebin, Li, and Fang (2009) regarded humanized design as "exploring human nature and application of human behavior, abilities, instincts limits and other characteristics and to create a good human-computer interaction" (p. 1079). X. Guo, Cao, Ye and Y. Guo (2010) suggested a humanized design must also be environmentally savvy (p. 517).

**Community involvement.** Lastly, community involvement was discussed in eight of the 106 collected articles. Some authors suggested that involvement within the community adds a local context to engineering solutions, thereby catalyzing the engineer's ability to help local community members solve a pressing need (Barke et al., 2001; Simrall, 1971). Community involvement may occur throughout all levels of the product development process (e.g. needs-identification, brainstorming, concept evaluation, prototype testing, evaluation, and implementation). Local residents may be involved in the projects by participating in surveys and interviews conducted by engineers (Saviz, 2004). The absence of community participation may result in the loss of opportunities for working towards social justice (Nieusma & Riley, 2010).

### Phase 2.2: Small Group Interviews

In Phase 2.2, we explored what empathy and care look like in an engineering context from the perspectives of engineering faculty by conducting small group interviews. The data collection procedures and results from this analysis is described in the following sections.

**Data collection.** We 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? We conducted three interview sessions with a total of seven engineering faculty members (Interviews 1, 2, and 3 had three, two, and two participants, respectively). The small group interviews were semi-structured and audio recorded. In total, sevens 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 2.2, we inductively developed a coding scheme through several iterations, a process known as "categorical aggregation" (Creswell, 2013, p. 199). We developed and used six coding categories to capture themes from the data. We used the frequency of codes to discover patterns from responses, to develop themes inductively from the data, and to bring to light any relevant or 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 transcriptions. Coder 1 initially coded 186 items. Coder 2 suggested 98 additions and 19 removals for this initial pool. Coder 1 reviewed the suggested additions, agreeing with 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 removal suggestions. The final total number of unsettled disagreements was 21 of a total 242 items coded, giving an overall agreement of 91.3%, which is considered a high level of inter-rater reliability (McMillan & Schumacher, 2001).

**Table 2.2:** *Themes and descriptions from interviews with 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 society as a whole, engineering as a profession is intrinsically empathetic and caring. |
| Motivating students to learn | Empathic 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 also enhance associated 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 engineering students to develop, although they may not be necessary for one to succeed as an engineer. |

**Phase 2.2 Findings**

The final coding scheme from practicing engineers' responses consisted of six themes and 58 categories. Table 2.2 lists these six themes and provides a narrative description of each. In the following passages, these 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 involving actually doing something about a situation. One participant stated, "Maybe empathy is a feeling, but caring is more of an active process".

One participant suggested 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 the situations where conflict arises to be exemplified by 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.*

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 engineering faculty members 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.** As 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… engineering provides devices and systems that improve the quality of life of civilization.*

Another participant initially viewed empathy and care as primarily playing a role on the "person to person engagement end". However, towards of the end of the interview, this participant re-thought 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 outsider perceptions of engineering as being empathic 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 suggested empathetic or caring engineering occurs whenever project 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 engineering faculty members thought empathy enabled 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 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. The student's professor brought the student to this advisor – the participant considered this to be 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 and 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 participant speculated that having these skills was "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 or 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 faculty member 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 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 2.3: Open Responses**

In Phase 2.3, we explored how trained engineers believe empathy and care look within an engineering context by analyzing open-ended survey responses from practicing engineers.

**Data collection.** The participants of Phase 2.3 were practiced engineers (n=348; 15% female, 84% male, four didn’t specify), alumni from the researchers’ home institution working in a variety of different fields with at least 1 year experience practicing engineering (n=338). By using an alumni list, we sent out an e-mail to these alumni, soliciting comments in regards 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" (Braun & Clarke, 2006, p. 79), was used to analyze 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 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 (a) agreed or disagreed with the codes paired with data, (b) 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 changes. The inter-rater reliability increased to 96% after the Round 1 adjustment.

**Phase 2.3 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 the six major themes most commonly represented within the comments. 76% of the text contained one or multiple categories or instantiations corresponding to these themes. Table 2.3 lists these six themes and provides a narrative description of each.

**Table 2.3:** *Themes and descriptions from written responses by practicing engineers*

| Theme | Description |
|---|---|
| Conceptual vagueness | The terms empathy and care are not parts of engineers' regular vocabulary as 20% of the 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. |
| 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 with respect to 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, then engineers tend to 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 or company. |

**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 general lack of use of this terminology in engineering discourse. As 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. One participant indicated this may be due to the definition of these phenomena varying 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.** 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."

Engineering alumni recognized that empathy and care were indispensable when they act in managerial or leadership roles. As one participant stated,

*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.*

Another participant equated "seasoned project managers" with "empathetic people", and a separate participant suggested, "Any manager of others needs to live on empathy and caring."

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 engineering alumni's comments, as one respondent wrote, "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 participants stressed the benefits of empathy and care in teamwork, writing, "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 rests 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,

> *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. As this participant explained:

*A young, immature person typically believes empathizing with them [other people] 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 the respondents recognized a tension between clients' needs and clients' wants, especially in regards 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 wrote, "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 and 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, 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 of empathy and care to economic gains. The bottom line seemed to be considered the driver of engineering practice, as one participant stated, "Business drives engineering, not the other way." Another emphasized the direct role of empathy and care on the bottom line, "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." Another respondent who suggested empathy and care align closely to engineering ethics suggested:

> *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 in a greater inclusion of empathy and care throughout engineering, "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 objectively.

**Embedding in the work culture.** Engineering alumni stated that whether engineers perceived the importance of empathy and care depended on the values emphasized by the company or their 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 if empathy and care would be valued more by engineers if they stem directly from overhead leadership's values. 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 this 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 education and practice, although these terms have lacked conceptualization and a coherent framework for their application and development. Conceptualizations of these constructs in fields such as nursing and psychology is similarly complex, despite concerted efforts to develop cohesion (e.g. see Kunyk & Olson, 2001). Existing engineering literature indicates relative value of these notions as embedded within similar vocabulary, yet this literature rarely uses the terminology of "empathy" and "care" explicitly. Similarly, these terms are uncommon vocabulary for practicing engineers, as 20% of the 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 these participants encountered these terms for the first time, the majority of these participants were able to strongly relate to the sentiment carried by the phenomenon. Furthermore, these participants seemed to find the terms useful as new analytic devices to reflect on and find new insights into their practice or profession.

The practicing engineers' insights led 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 comparisons to the five conceptualizations of empathy depicted by Kunyk and Olson (2001) as described in the 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" (p. 138).

*Empathy as a human trait* suggests empathy is innate and can only be identified and refined. Engineering faculty members never explicitly discussed this notion, and practicing engineers did not stress it. Engineering faculty members seemed to assume that empathy may be intrinsic to certain acts, although it was unclear whether faculty believed 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. These participants did, however, emphasize the role of an empathic and caring faculty member in students' motivations within the classroom.

*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 this study's participants (e.g. when engineering faculty presupposed empathy may be cultivated in team-oriented activities). Rather than focusing pragmatically on *how* empathy or care may be cultivated, participants (faculty and practicing engineers) discussed in abstract terms *why* empathy and care should be cultivated in the contexts of success, professionally or academically. In so doing, the participants in this study seemed 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 the participants indicated empathy and care are integral to the core of their engineering practice, this study cautiously supports the notion that these terms are not easily placed in the dichotomy of hard versus 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 empathy requires and enables greater understanding of people and better communication skills, and thereby was beneficial to team-oriented activities and when working with clients or other stakeholders. These participants were again speaking of the utility of empathy, but this time specifically in the process of communicative activities. In addition, these participants did not emphasize the back-and-forth orientation of perspective-taking as described by Kunyk and Olson here.

*Empathy as caring* merges an action component with other conceptualizations of empathy. The participants in this study tended to differentiate between the two phenomenon, empathy and care, which may be due to the framing of the study – we asked participants to separately conceptualize the two concepts. Caring, as seen by the participants, involved the act of doing. While empathy, in participants' conceptualizations, 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 between two individuals that develops over time where empathy is present. It may be cultivated within one-on-one, person-to-person relationships. In this study we saw two different conceptualizations related to this: (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 the "one million users who cross this bridge". In this perspective, the consideration for the perspective of a single user gives way to an aggregate perspective. (2) One-to-one-oriented conceptualizations existed in the participants' views 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 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?" the participants in this study seemed to more commonly 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 engineering as a whole profession, as engineers commonly purport that their profession saves or better peoples' lives and society as a whole (Downey, 2012). For this to be truly achieved, engineers must understand the perspective and ultimate needs of the collective stakeholders. On another hand, empathy seems to be the means to attain personal goals such as becoming better in the domains of teamwork, communication, management, client relationships, and leadership. Both of these perspectives are not mutually exclusive, yet may generate tensions 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 this study echoes the sentiments of empathy being *core* as described by Walther, Miller, and Kellam (2012). Most of the participating engineering faculty explored mechanisms whereby empathy and care exist in engineering education already (albeit indirectly), whereas fewer pointed to an already overcrowded curriculum, suggesting these phenomenon were perhaps an unnecessary addition. With practicing engineers we see less presence of these tensions with a more utilitarian stance towards the phenomena, 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 become.

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 phenomenon in coherent and meaningful frameworks (e.g. Kunyk & Olson, 2001). When we situate empathy and care within engineering, the notions may look similar to 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, as a societal or macro 'stakeholder' becomes the 'individual' the engineer strives to empathize with or care for.

This study shows the complexity of these phenomena as vivid when examining the wide array of findings. We feel comfortable emphasizing that the participants we interacted with suggested 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.

This study's 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 phenomena 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, this study indicates that the quality of the technical work is perceived to increase as well. We would further encourage engineering educators to find novel ways of incorporating empathy and care into the teaching of the 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 curriculum 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 societally impactful profession, and thereby increase and retain diversity within the student body.

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## LIMITATIONS

This study provides preliminary insight into how empathy and care are conceptualized within engineering from the perspectives of existing literature, engineering faculty and trained engineers. While this study 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 attention on how such pedagogy may be brought to 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 and care, the small number of faculty participating in the interviews and the short nature of the statements from practicing engineers.

The next chapter consists of a richer exploration of practicing engineers’ perceptions regarding the presence and importance of empathy and care to their professional careers. This subsequent chapter serves as a vehicle to triangulate and expand the findings from this chapter.

CHAPTER III

# INSIGHTS FROM INDUSTRY: A MIXED METHODS EXPLORATION ON THE ROLE OF EMPATHY AND CARE IN ENGINEERING PRACTICE

Manuscript by Justin Hess, Johannes Strobel, Rui Pan, & Carrie Wachter Morris

# CHAPTER III. INSIGHTS FROM INDUSTRY

## ABSTRACT

**Background**: Existing calls for change within engineering and engineering education have motivated this study. Our focus was on two skills or dispositions which seem to underlie essential engineering habits of mind for the holistic engineer of the future: empathy and care.

**Purpose**: We explore, from the perspectives of practicing engineers, in what ways empathy and care already exist within engineering practice, and in what ways empathy and care may be most important to engineering practice. Furthermore, we seek to understand if the deemed importance of empathy and care to engineering practice varies by gender or years of experience of practicing engineers.

**Design/Method**: This study uses a concurrent triangulation mixed methods research design to approach the research questions, where quantitative and qualitative findings each inform the final result equally. For the qualitative portion, we use a combination of phenomenology and thematic analysis to explore (a) conceptualizations of empathy and care from the perspective of practicing engineers and (b) the essence of empathy and care within engineering practice through interviews with 25 practicing engineers. For the quantitative portion, we analyze a 37-item questionnaire, first using exploratory factor analysis (n=1574) and second using non-parametric testing (n=1481) as normality assumptions were invalid.

**Results**: First, thematic analysis led to the emergence of 11 conceptual themes along three categories and 13 phenomenological themes along four categories. These phenomenological categories included (a) design outcomes, (b) personal outcomes, (c) relational outcomes, and (d) broader ideas. Second, using the survey's derived six-factor structure, this study found that practicing engineers with greater years of work experience were significantly more likely to perceive empathy and care as existing in engineering practice and as important to their work.

**Conclusions**: Empathy and care exist within engineering, and practicing engineers are already conscious of ways in which they see these skills or dispositions are important (or even essential) to their own day-to-day practice. While empathy and care may appear differently in engineering workplaces depending on the context or culture of that work environment, the engineering participants in this study regarded empathy and care as highly valuable within their careers. We explore implications for engineering educators as part of the data integration.

***Keywords****: Empathy, care, empathic design, engineering education*

## INTRODUCTION

This study continues the discussion on what skills or dispositions engineers should possess (NAE, National Academy of Engineering, 2004). Specifically, we focus on two attributes that seem to underlie NAE's and the National Research Council's (2009) "habits of mind", empathy and care. Smith, D. W. Johnson, and R. Johnson

(1981) suggested more than 30 years ago that engineering learning goals fall into three related categories: technological, intrapersonal, and social-technical competencies. Three decades later, the drive to incorporate competencies beyond technological into engineering education persists. Adams and Felder (2008) suggest this is widespread now more than ever because today engineers are required to “develop innovative products, exercise new and unfamiliar technical and profession skills, and function in an increasingly global environment” (p. 239). Niewoehner and Steidle (2009) suggest professional engineers must develop certain intellectual virtues to thrive in this dynamic professional environment. They call one of these virtues intellectual empathy, which they describe 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. (p. 11)

Within engineering literature, explicit attention to empathy and care has been minimal, as shown in a recent pilot literature review research study (Strobel et al., 2011). A follow-up extensive literature review and analysis of short statements from practicing engineers further explored the role of empathy within engineering (Strobel, Hess, Pan, & Wachter Morris, 2013). As Chapter 2 showed, like-terms such as “users’ needs” and “solidarity” are common. Yet, the lack of explicit use of “empathy” and “care” in engineering literature might indicate that a concerted discourse of these constructs is missing. Utilization of these terms in recent years, however, is growing. For example, empathic design has been deemed the most comprehensive category of human-centered design ( Zoltowski, Oakes, & Cardella, 2012) and empathy is being incorporated into and measured within engineering education (Rasoal, Danielsson, & Jungert, 2012; Walther, Miller, & Kellam, 2012).

Beyond engineering, empathy has been speculated as the essential ingredient for human subsistence (de Waal, 2009; Rifkin, 2009). de Waal (2009) claimed that humans do not survive through elimination of one other, but through mutual collaboration and cooperation. Rifkin (2009) provided a historical overview of civilization's progression and argued that with societal increases in energy consumption has come a greater awareness of others, and thereby a global empathic consciousness.

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 (Iacoboni, 2009) and that a lack of empathy, as evident via the dysfunction of the mirror neuron system, is directly related to autism (Iacoboni & Dapretto, 2006). This lack of empathy has been shown to be highly correlated with an evil aptitude (Baron-Cohen, 2011). Baron-Cohen suggests the absence of this empathic disposition is not the root cause of evil, but closely tied to it. There is a large philosophical debate between the empathy-altruism hypothesis, with some authors suggesting that empathy is closely tied to altruistic motivation, where an individual is entirely driven to help others, absent of ulterior egoistic motivations (Batson, Ahmad, & Lishner, 2011; Stich, Doris, & Roedder, 2012).

The Gallup organization uses a Strengths Finder personality instrument, which provides survey takers with a list of their top strengths out of a list of 34, including empathy. Rath (2007) and later Rath and Conchie (2008) have designed the instrument as a tool for individuals to discover their top strengths. Their premise is that individuals should position themselves in work environments where they may thrive with their top existing strengths, rather than improving their weaknesses. Using empathy as an example, the implication for engineering educators or employers would be that if an engineer or engineering student is lacking in empathy to not to put that individual into a situation where s/he needs empathy to succeed. Conversely, if an engineer is empathetic, it would be advisable to place this engineer in situations where s/he may use that skill to succeed.

**Purpose and Research Questions**

This study explores the situations within engineering either where the combined construct of empathy/care already exists or where practicing engineers believe empathy/care should exist. The purpose of this study was to explore the presence of empathy/care and its role within engineering by looking in-depth at how empathy/care already exist in engineering practice according to practicing engineers. This research was guided by the following research questions, (a) "How do practicing engineers conceptualize empathy and care?", (b) "From the perspective of practicing engineers, to what extent does empathy and care exist within their engineering practice?" and (c) "From the perspective of practicing engineers, to what extent is empathy and care important to their engineering practice?"

**Literature Review: Conceptualizations of Empathy and Care Outside of Engineering**

The common idiom describes empathy as putting yourself in another's shoes. Within academic literature, it is commonly divided into one, two, or even three components: (a) knowing what another is feeling, (b) feeling what another is feeling, or (c) responding to another (Levenson & Ruef, 1992). Wispé (1986) suggested empathy is best understood *only* as a way of knowing, as opposed to sympathy which involves feeling. Lawrence et al. (2006) distinguished between "cognitive" and "affective" empathy, where the cognitive aspect involves "understanding and predicting someone else's mental state" and the affective aspect involves "experiencing an emotion as the result of someone else's mental state" (p. 1173).

Despite these nuances, differentiating between "cognitive" and "affective" empathy is not always possible. For example, Hoffman (2000), who considered empathy the core component of ethical reasoning, defined empathy as an "affective response more appropriate to another's situation than one's own" (p. 4), but even Hoffman emphasized this "affective response" is informed by cognitive capacities such as perspective-taking and mediated association. Oxley (2011), who also placed empathy centerfold within ethical decision-making, regarded the affective dimension as essential to being empathic as it enables a congruent emotion with another. Nonetheless, empathic accuracy requires one to have a clear understanding of self. Studies have shown when individuals blur the self-other boundary, their empathic accuracy declines (Decety & Jackson, 2004; Lawrence et al., 2006). Hence, perspective-taking requires the individual to interpret another's perspective through that individual's own lens. The accuracy of this lens will be situation specific and will depend on a number of factors such as cultural similarities or differences and one's relationship with the other (Hoffman, 2000; Ickes, 2009).

Care is a similarly complex phenomenon, with numerous and highly variable language uses. Often, scholars frame care within the scope of empathy. This is similar to one of the most prominent uses of empathy within nursing literature, where empathy has been depicted as care, which in turn involves concern for the outcome of an intervention (Kunyk & Olson, 2001). Similarly, B. Newman and P. Newman (2012) suggested caring builds on emotions aroused by empathy. Sutherland (1993) depicted empathy as a process which starts with cognition, then affection, culminating in a behavioral response (e.g. care). M. H. Davis (1996) even suggested that the empathic process culminates in a caring response and thereby this "response" is akin to an empathic outcome. All of this framing is similar to the findings from Chapter 2.

Throughout the survey disseminated in this paper, participants were asked to indicated how strongly they felt according to their deemed importance of empathy **and** care as a single construct. We did not define these terms for the participants because a concise definition would be limiting given the rare use of the terms within engineering and the exploratory intent of this study. Our aim was to develop an emergent engineering-specific conceptualization of empathy and care. Therefore, the initial guiding research question in the qualitative portion of this study is, "How do practicing engineers conceptualize empathy and care?" To answer this, in interviews we ask participants to depict their understanding of empathy and care, along with how they see empathy and care as similar or different. The resulting themes from this research question form the conceptual foundation for the subsequent analyses within this study.

## CONCURRENT TRIANGULATION MIXED METHODS DESIGN

This research design uses a mixed methods approach to address the research questions. Creswell, Plano Clark, Gutmann, and W. Hanson (2003) define a mixed methods study as "the collection or analysis of both quantitative and/or qualitative data in a single study in which the data are collected concurrently or sequentially, are given a priority, and involve the integration of the data at one or more stages in the process of research" (p. 212). Smith (2004) suggests a common usage of mixed methods research "is to combine qualitative and quantitative data and methods to study the same processes, to come at them from a different angle and attempt to take a picture of them with a different camera" (p. 127).

In this study, we use a concurrent triangulation research design to realize the advantages of these distinct methodologies (Borrego, Douglas, & Amelink, 2009; Creswell & Plano Clark, 2011). The concurrent triangulation design relies on two methods, one qualitative and one quantitative, to corroborate or cross-validate multiple findings within a single study. Creswell et al. (2003) explain, "This design generally uses separate quantitative and qualitative methods as a means to offset the weakness inherent within one method" (p. 229).

Figure 3.1 depicts the overall methodology, slightly adapted from Creswell et al.'s (2003) text. In this study, the quantitative data collection process enabled us to collect qualitative data. After participants completed the "Empathy and Care Survey", we invited purposefully selected participants to partake in follow-up interviews. We analyze the survey data and the interview data separately and then combined the data for interpretation, as Figure 3.1 shows. The quantitative data collection serves as a vehicle for collecting qualitative data. Likewise, the analysis of the qualitative data, particularly the thematic mapping of participants' conceptualizations of empathy and care, allows the interpretation of the quantitative results as aligned with the participants' conceptualizations of the research phenomena (as opposed to scholarly conceptualizations or our own). The final step, the combined interpretation, enables a holistic understanding of the importance and current existence of empathy and care within the practice of engineering practice, as informed by practicing engineers.

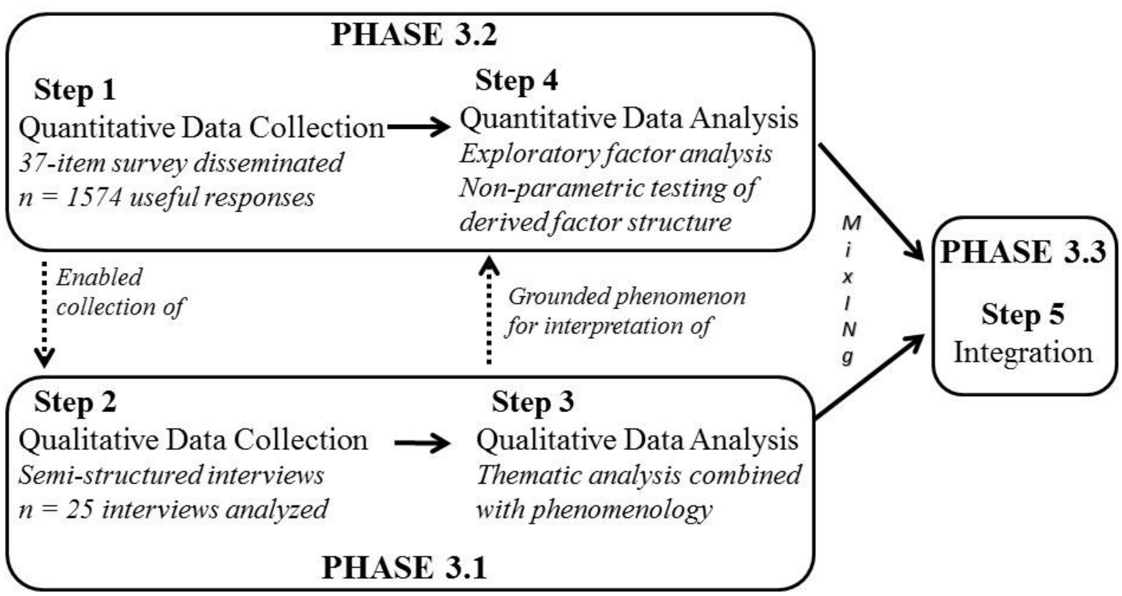


**Figure 3.1**: *Concurrent triangulation research design*
*(Adapted from Creswell, Plano Clark, Gutman, & W. Hanson, 2003, p. 236)*

As Figure 3.1 shows, the data collection and analysis proceeds in a series of steps. Further, this study depicts the qualitative, quantitative, and mixed methods components in separate phases. Phase 3.1 includes the qualitative data collection and analysis, Phase 3.2 the quantitative, and Phase 3.3 is where the 'mixing' occurs. This study proceeds in this phase ordering, with each step further described in its corresponding phase.

## PHASE 3.1: QUALITATIVE METHOD AND RESULTS

Phase 3.1 of this study provides an analysis of 25 interviews with practicing engineers. The intent of this section is to ground conceptualizations and deemed importance of the phenomena, empathy and care, in the words and contexts of practicing engineers. As such, the qualitative portion seeks to address the following research questions:

1. How do practicing engineers conceptualize (a) empathy, (b) care, and (c) differentiate between the two?
2. In what ways do practicing engineers experience empathy and care as existing within their practice?
3. In what ways do practicing engineers perceive empathy and care to be important to engineering practice, in general?

Qualitative research is a passageway to enhancing understanding of quantitative results, the underlying topic, and to develop new theories. K. Newman (2004) suggests, "The intrinsic value of qualitative research is in its capacity to dig deeper than a survey can go, to excavate the human terrain that lurks behind the numbers" (p. 106). In this study, the qualitative component led to the development and expansion of engineering-specific conceptualizations of the research phenomena, as well as the perceived importance and existence of empathy and care within engineering practice.

Mahoney (2004) suggests "qualitative research offers some distinctive advantages for achieving measurement validity" (p. 98) when compared to quantitative research, as the variables are situated in the context of each individual participant, the variables are flexible, and meanings of the data are iteratively developed by negotiation amongst the research team. This qualitative exploration of the research phenomena from the perspective of participants is a process of attaining measurement validity which is essential for interpretation of the quantitative results.

We use phenomenology as an overarching qualitative research framework (van Manen, 1990) paired with thematic analysis specifically during data analysis (Braun & Clarke, 2006). Phenomenology describes "the meaning for several individuals of their ***lived experiences*** of a concept or a phenomenon" (Creswell, 2007, p. 57). The purpose of phenomenology is to sample a representative group of individual experiences to provide a summative description of the universal essence of some phenomenon (van Manen, 1990). Scholars often conducted qualitative work by interviewing individuals who have experienced that phenomenon. In this study, the phenomena we explore are empathy and care in the context of engineering practice. The participants are engineering practitioners – the actual individuals who have experienced the phenomena within the context that we are exploring. All of these participants were volunteers. We assumed participants who volunteered were conscious of the presence of empathy and care within their engineering work. This explicit consciousness of the participants is a philosophical necessity for performing the phenomenological work described herein (van Manen, 1990).

Phenomenology rests on a number of philosophical perspectives. First, researchers must conduct phenomenological work with a blank slate mentality, setting aside their prior premises in order to examine the phenomenon from the novel perspectives provided by participants (Moustakas, 1994). In order to ground conceptualizations of empathy and care from the participants' perspectives, we explicitly asked participants for their conceptualizations at the beginning of each interview. The researchers did not prioritize *a priori* codes during the analysis of interviews, although the research team did have a set of pre-established codes based off the research team's previous work (specifically, Chapter 2). Nonetheless, we ground the results in the participants' phrases and used select passages to exemplify emergent themes.

Second, phenomenology is an interpretative epistemological process in which the researcher is the mediator (van Manen, 1990; Weber, 2004). In the context of phenomenology, the process of thematic analysis is one of recovering embodied themes from the data depictions, where a theme is defined as "an element (motif, formula or device), which occurs frequently in the text" (p. 78).

Third, the process of thematic analysis itself should not be simply reduced to one of a frequency count but is better understood as "a process of insightful invention, discovery or disclosure" or "a free act of 'seeing' meaning" (p. 79). Themes are the means towards an understanding of the essence of some phenomenon, providing "control and order to our research and writing" (p. 79).

**Data Collection**

The research team received human subject research approval from the appropriate institutional review board at the researchers' institution. Interview participants first completed a survey and at the end of the survey had the option to participate in a follow-up interview. From the pool of 73 interviews we conducted, we purposefully selected to analyze transcripts with a goal of stratifying the sample according to the following variables: (a) a total number of 25 interviews, an adequate number as suggested by Guest, Bunce, & L. Johnson (2006) for data saturation, and the upward limit suggested for saturation within phenomenology (Creswell, 2007), (b) baccalaureate degree according to population from the alumnae database, (c) gender distribution of engineers by population in the United States (Female = 35.2%; Male = 64.8%, according to Falkenheim & Burrelli, 2012), and relatively equal categorical variability in (d) age and (e) years working as an engineer. We selected interviews with 16 males and 9 females for analysis, accounting for 64% and 36% of the sample, respectively. Figure 3.2 shows the current engineering discipline of participants, along with their reported academic background. Table 3.1 shows the age distribution of participants along with their number of years working in engineering.

**Table 3.1**: *Age and years of engineering work experience of interview participants*

| Age Range | | Years working in Engineering | |
|---|---|---|---|
| 20-29 | 3 | 0-9 | 5 |
| 30-39 | 6 | 10-19 | 5 |
| 40-49 | 3 | 20-29 | 5 |
| 50-59 | 5 | 30-39 | 4 |
| 60-69 | 4 | 40-49 | 3 |
| 70-79 | 2 | 50+ | 2 |
| Unknown | 2 | Unknown | 1 |

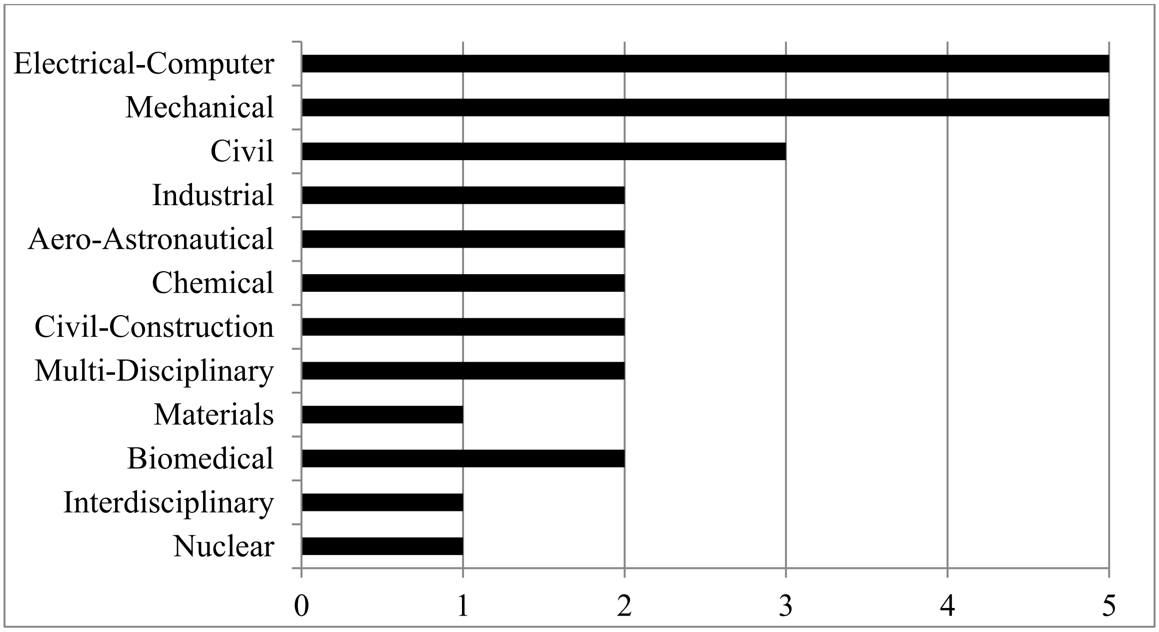


**Figure 3.2**: *Engineering practice and engineering degree of interview participants*

The interview protocol was semi-structured. We specifically asked participants to reflect on their experiences of empathy and care in their own work, along with broader reflection questions regarding the importance of empathy to engineering as a whole. We recognized that participants may conceptualize empathy and care differently. Thus, the interview protocol in this study was similar to our previous study (Hess et al., 2012) where we began by allowing the participants to define empathy and care and the conversations to stem from these definitions. The interviews included 10 higher-level questions with multiple sub-questions for each. See Appendix A for the interview protocol.

We performed the interviews over the phone using Skype and we used CallGraph software to record the interviews. Four different graduate students performed interviews, with the first interviewer (myself) training the other three. The training session involved reviewing the interview protocol and letting the other interviewers sit in on an interview conducted by the first interviewer, followed by a question and answer session between the first interviewer and the other three.

**Process of Thematic Analysis**

Silbey (2004) suggests, "The mode of analysis rather than the type of data more appropriately describes work as qualitative" (p. 122). Thematic analysis involves the development of themes which "captures something important about the data in relation to the research question, and represents some level of *patterned* response or meaning within the data set" (Braun & Clarke, 2006, p. 82). Deductively, the guiding questions included in the survey protocol (see Appendix B) and our previous research (see Chapter 2) provided codes used for analysis, although these codes were not rigid. We captured novel ideas by developing new codes and themes. Hinkin (1998) suggests this form of inductive item generation "may be appropriate when the conceptual basis for a construct may not result in easily identifiable dimensions for which items can then be generated" (p. 107). This step in the research design allowed us to capture engineers' conceptualizations, understanding of the existence, and perceived importance of empathy and care in their practice without an altogether inhibiting influence from our previous work or the existing scholarly literature.

The interviews chosen for analysis were primarily those conducted by the two coders in this study; 17 from Coder 1, a male PhD student in Engineering Education and, 7 from Coder 2, a female PhD student in Engineering Education, along with one interview from one of the other interviewers, resulting in a total number of 25 interviews retained for analysis. Figure 3.3 presents an overview of the coding process.

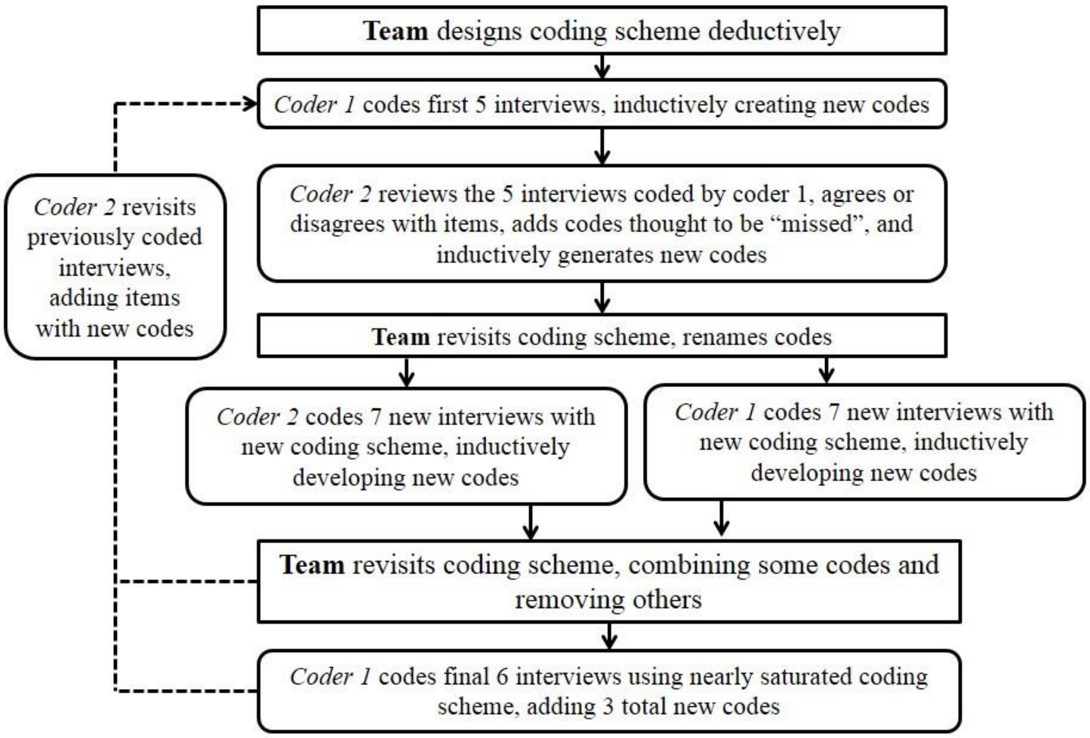


**Figure 3.3**: *Thematic analysis coding procedure*

After each of the coding phases the research team gathered and discussed the coding framework, as shown in Figure 3.3. The coding scheme was refined in these meetings where some codes were condensed and others separated. Throughout this process, Coder 1 and Coder 2 each inductively created new codes until, as indicated in the final step, only a very few codes were created, suggesting coding saturation. After we created a new code, we revisited previously coded interviews, examining and coding for the newly developed code.

We sought inter-rater reliability after the first round of coding to ensure that the two coders were in alignment with the broader coding framework. After Coder 1 coded the first five interviews (adding a total of 314 items), Coder 2 went through the coding document and agreed or disagreed with existing codes, added codes thought to be missed, and created new codes representing new ideas. Coder 2 disagreed with 13 of the existing codes, representing an agreement rate of 95.9%. Coder 2 created five new codes and added a total of 28 “missed” codes, increasing the number of items coded by nearly 9%.

The product of phenomenological work is the essential, invariant structure, or the essence of the phenomenon, which is best understood as “the common experiences of the participants” (Creswell, 2007, p. 62). We tried to capture the essence of empathy and care within engineering by using codes and themes. By inventing, discovering, and disclosing these themes we hoped to give “shape to the shapeless” (van Manen, 1990). The themes we present appear in the majority of interviews analyzed. These themes are not mutually exclusive, as several represent similar ideas. We present each theme with a summative description, followed by exemplary passages taken directly from the interviews. First, we explore practicing engineers’ conceptualizations of empathy and care. Second, we explore engineers’ experience of empathy and care within their work, alongside their deemed importance of empathy and care within engineering as a whole.

**Conceptual Themes**

In this section we address the research question, “How do practicing engineers (a) conceptualize empathy, (b) conceptualize care, and (c) differentiate between the two?” Each of these sub-questions led to the generation of three or four sub-themes. We end this section by framing empathy and care as a single construct and by considering what this construct includes according to this study's participants. Table 3.2 provides an overview of the results of this thematic analysis. The themes generated in respect to these research foci we will refer to as *conceptual* themes throughout the remainder of this chapter.

**Table 3.2**: *Conceptual themes from interviews with practicing engineers*

| What is empathy? | What is care? | Contrasting empathy and care |
|---|---|---|
| Understanding another | Behavioral response | Care is behavior resulting from empathy |
| Experiencing the other | Emotive concern | Empathy ≠ care |
| Seeing from the other's lens | Intrinsic motivation | Empathy and care are nearly synonymous |
| Understanding context | Professional duty | |

**Engineers' conceptualizations of empathy**

In this section we address the research question, "How do practicing engineers conceptualize empathy?" The following four themes were most pervasive from the analysis:

1. Empathy as understanding another's or others' thoughts or feelings
2. Empathy as imaginatively experiencing what the other is experiencing
3. Empathy as seeing the world from another's or others' viewpoint
4. Empathy as understanding the surrounding world context

***Empathy as understanding another's or others' thoughts or feelings***

This theme suggests empathic understanding is achieved by performing cognitive or affective perspective-taking tasks, such as pluralistic reasoning (e.g. reasoning from the other to the self, then reasoning back to the other), or by imagining oneself in the other's position. As one participant described, "I would define empathy as being able to relate to someone else's emotions, seeing where they're coming from, and being able to understand their reactions and emotions and feelings." Another participant emphasized emotional comprehension, stating, "Essentially empathy is a quality of understanding between two individuals on the emotional plane." Empathy as understanding may require other skills, such as listening or actions such as two-way discourse. For example, one participant described empathy as "the characteristic or the ability of the listener to understand the position, or the side, of the other person that's talking to them." This theme did not necessarily involve an individual becoming concerned with how something will impact another or others, be it either positively or negatively.

***Empathy as imaginatively experiencing what another experiences***

This theme suggests empathy is the cognitive process of imaginatively placing oneself in another's position and thereby literally experiencing what another is experiencing or has experienced. As one participant described, "To have a sense of what the other person feels…. it's more than sympathy. It's more like living the other person." Another participant thought empathy may be oriented towards an individual or a whole group, noting "in the case of empathy I am able to place myself mentally in the shoes of that individual or group of individuals."

***Empathy as seeing the world from another's or others' viewpoint(s)***

This theme emphasizes the perceptual orientation of empathy, namely, seeing the world from another's perspective. One participant noted, "Empathy really is seeing other people's viewpoints from, from their… where they stand." Some participants noted that through the process of trying to see from another's perspective leads one to internalize that individual's viewpoint, thereby expanding one's own perspective on an issue or task.

### *Empathy as understanding the surrounding world context*

This theme depicts empathy as a holistic understanding of the surrounding world or environment. As one participant noted, "Empathy to me is about, well I'll say it's about context. It's about being aware of what's going on around you and other people around you." This participant continued to explain, "It's understanding a relationship of one's self to the larger world and the people in the larger world." Another participant explained, "Empathy is just the, a real feel for the situation and the people in, you know, the people involved."

## Engineers' conceptualizations of care

In this section we addressed the research question, "How do practicing engineers conceptualize care?" Here four themes were most pervasive following the analysis:

1. Care as an active behavioral response
2. Care as emotive concern for another's or others' well-being
3. Care as intrinsic motivation or any desire to do something well
4. Care as professional obligation or duty

### *Care as an active behavioral response*

This theme suggests that care is a behavioral response resulting from an internal drive or external event. Many participants emphasized the response is geared towards helping another. As one participant described it, "Caring means that you actively are looking out for the well-being of somebody else, or something. It is important to you, personally." Another participant put care in the context of engineering, stating, "As engineers obviously we build things in a world that really help people, that's what engineering's about, and that is an expression of care, as we build habitations and clean water systems and medical systems and devices."

***Care as emotive concern for another's or others' well-being***

This theme suggests that care is the internal feeling of concern for another. One participant described care as "an emotion that you feel towards people. That you want to help them and be considerate of their feelings." Another participant stated, "Caring I think would be concerned about the other people." Another put it in the context of the manager-employee relationship, stating, "Caring to me means making sure you are careful about everybody and their health and just on the job caring for everybody means making sure everybody is making it home at the end of the day."

***Care as intrinsic motivation or any desire to do something well***

This theme suggests that caring is one's intrinsic desire or motivation to do something well. As one participant noted:

> *I think care involves you're doing something because you get some satisfaction out of the outcome. Meaning you're doing it because it's the right thing to do, and because you get a sense of satisfaction out of volunteering or helping others.*

Another participant situated care in the context of their workplace setting, explaining:

> *Well from my work experience I really respect the company that I work for so I put extra effort in and I guess you could say care when doing work or putting plan*

> *sets together to go out to the middle whereas somebody may say well this is good enough this is not the final it's the middle. I want my company to look as good as possible so I tend to put more care into my plan sets than a lot of my other co-workers.*

***Care as a professional duty or obligation***

This theme suggests care is one's professional obligation or duty. As one participant explained:

> *There is the other care which is used in professional circles. The standards of care is creeping into engineering practice but it is very wide spread in medical right now. The standards of care as I understand it there is that I have exercised appropriate diligence in my work. My work would be comparable to another professional of similar background performing similar work.*

Another participant situated care in the context of safety, explaining, "So, to me, caring is making sure that our product is safe, that they provide a level of safety that is maybe even above what the customer, or the flying public has become accustomed to seeing."

**Empathy in relation to care**

In this subsection, we address the research question, "How do practicing engineers differentiate between empathy and care?" Three themes were most pervasive from this analysis: (a) care as a behavioral response resulting from empathy, (b) empathy and care as near-synonyms, and (c) empathy and care as non-synonymous

***Care as a behavioral response resulting from empathy***

This theme, which was by far the most pervasive in the section, suggests that care is a behavioral response resulting from empathy. This response may be in the form of an engineering design solution, active communication, or helping in any manner. As one participant explained:

*I think you can empathize with the, with somebody without act – you can empathize and understand where something, someone is coming from and do nothing about it. But if you care about it, then you take that extra step and actually act on the empathy.*

Another participant stated:

*I think empathy can lead to care. They're related in that way. If one is really aware of one's context and especially the people in that then being aware can motivate one to care. You know, invest something, energy, money, emotion, in the well-being of that person. So I could see empathy leading to care.*

Another participant depicted empathy as "inward" and care as "outward", stating:

*I see empathy as sort of an inward action it is me internalizing something and determining that I can relate or understand the situation of my user. I see care as putting that into action. I see care as the outward response to my empathy. So if I can differentiate as one as an inward behavior and I see the other as a very much outward behavior.*

Another participant put empathy and care in the context of engineering, noting:

> *I think empathy is the drive or desire to ensure that the customer is getting everything that they want out of that product. I think that care is making sure that product is safe, is going to be environmentally sound, is going to be something that is good for people and the environment. It's a different aspect of a similar thought, but one is trying to reach the maximum performance that the customer desires, and the other is trying to make sure that design is grounded in a safe flight environment that you can count on, even in emergencies.*

***Empathy and care as near-synonyms***

This theme suggests that empathy and care are nearly identical phenomena. One participant stressed, "Care really is tied with empathy. Care to me is part of having empathy. Empathy is not only understanding people's situations, but is caring about how you interact, and how people interact with you." When asked if there were *any* nuances between the two, the participant reiterated, "It's not different. It really isn't. They are very much tied hand in hand," and "I don't think you can split the two." A separate participant defined empathy in terms of care, stating, "My definition of empathy would be caring about your work, caring about the people that you work with, and caring about the good that your company does." Another participant explicitly stated, "Well I guess I, there kind of… to me they're almost synonymous. Having empathy is caring for everybody involved."

***Empathy and care as non-synonymous***

There were two primary differentiations underlying this theme. First, participants noted that empathy, in terms of understanding others, does not equal care, defined as having emotive concern for another. As one participant explained, “You can be empathetic but not care. And you could care, you could worry about somebody, but not really understand what they’re going through.” Another expanded this idea, noting (in reverse of the previous themes but in support of the broader idea), “I think empathy... it’s a more dynamic response requiring an actual interaction where caring is essentially the frame of mind, the position of the heart, your attitudes towards the other individual.”

Second, participants noted that empathy, in terms of understanding others, does not equal care, defined as a behavioral response. As one participant explained, "I think it’s, it’s quite possible to care for someone without feeling empathy. You can show care, you can exp—you can literally provide care without having empathy.” Another participant expanded this idea, stating, “With empathy, empathy is a greater understanding of what the other people are… their point of view as opposed to caring. I care and I want to help but you may not understand as well what it is that these people go through every day.”

**Framing empathy and care as a single construct**

The consensus amongst participants was that empathy and care are very similar phenomena. While several participants explicitly noted nuances differentiating the two, nearly all participants depicted the terms as inter-related. The remaining structure of the interview protocol asked participants questions in reference to empathy and care, but we indicated that participants may differentiate between the two in their responses. For example, throughout interviews when we asked participants, “In what ways are empathy and care important to your work?”, “How are empathy and care important for your discipline?” Following these queries, we would often add, “You may differentiate between the two.”

Most commonly, participants chose to combine the phrasing of “empathy and care” in their response, depicting empathy and care as a singular construct. We follow this lead throughout the remainder of this study, reiterating for clarity that most commonly participants depicted care (a) emotively, as concern for another and (b) pragmatically, generally resulting in some action. In the quantitative section, we analyze the constructs of empathy and care as a unit with the paired construct of empathy/care including understanding others emotively and cognitively, along with acting on that understanding.

**Phenomenological Themes**

In this section we address the research questions, “In what ways do practicing engineers perceive empathy and care as existing within engineering practice?” The results fall into four broad categories: (a) **design outcomes** of being empathic/caring as an engineer, (b) **personal outcomes**, or cognitive abilities improved as a result of being empathic and caring, (c) **relational outcomes**, or interpersonal skills improved as a result of being empathic and caring, and (d) **broader ideas** revolving around empathy and care situated within engineering. Each of these categories contained three to four sub-themes that were present in the majority of interviews, for a total of thirteen themes.

The themes presented in Table 3.3 appeared in more than half of the interviews analyzed as evidenced through their underlying codes. These themes are not mutually exclusive, as the majority represent similar ideas with slight nuances. We present each theme with a summative description alongside a few exemplary passages taken directly from the interviews. In this way, we give voice to the participants through thick description (Geertz, 1973) thereby allowing the reader to decide the extent to which their interpretations align with our own.

**Table 3.3**: *Phenomenological themes from interviews with practicing engineers*

| **A. Engineering Outcomes** | **B. Personal Outcomes** | **C. Relational Outcomes** | **D. Broader Ideas** |
|---|---|---|---|
| Meeting needs of others | Understanding others | Building relationships, trust, & respect | Necessary skills |
| Delivering optimal results | Broader impact awareness | Teamwork and solidarity | Context dependence |
| Helping others, perhaps altruistically | Broadening one's own perspective | Effectively communicating & interacting | Undervalued dispositions |
| | | Managing and leading others | |

**Category A: Engineering outcomes**

The themes corresponding to this category describe the nature of resulting engineering outcomes when empathy and care guide the engineering process. The three themes forming this category, in order of pervasiveness, include (a) meeting needs of others, (b) delivering optimal results, and (c) altruistic helping behavior.

***Theme A1: Meeting needs of others***

This theme suggests empathy and care are both helpful and nearly always required in order to meet some need of one or multiple users, whether or not those users are consciously aware of that need. As an example, a 37 year old male, chemical engineer by training but working as a consultant during the time of the interview, stated:

> *You have to understand the needs of your audience before I think you can effectively deliver – to meet their needs. I think if you lack empathy there's going to be a disconnect. You're going to be more likely to teach or deliver or deploy what you think is best versus what you've been told or what you could have researched what would be best*.

Another participant, a 77 year old male who was retired during the time of the interview but had 54 years of experience as a computer engineer, provided an example related to engineering design, specifically involving the design of computers on-board Navy ships. He understood that the employees generally did not clean the air filters within the computers, most likely because these air filters were not in plain sight. Therefore, he created a solution based on his anticipated behavior of users and designing with them in mind:

> *I intentionally put the air filters on the very front outer surface of the computer… so that the air filters would always be in vision… The reason I did that is because it's important that those air filters be kept clean and because they were visible in the front the chief, the Navy Chief who comes around and inspects, would see them immediately*. *Whereas, if the filters were stored inside like they are on most electronic equipment they don't get seen so they don't get noticed so they don't get cleaned*.

***Theme A2: Delivering optimal results***

This theme indicates that empathy and care provide the capability or the motivation to design and deliver *optimal* engineering solutions. The capability to design optimal results may derive from other empathetic or caring related skills (e.g. understanding others, communicating with others). The motivation to deliver optimal results may be other-oriented (e.g. 'this matters to others') or intrinsic (e.g. 'this matters to me'). One participant, a 33 year old nuclear engineer with 9 years of engineering experience, explained this theme in terms of quality:

> *…sloppy work on your part could negatively affect somebody, perhaps in some sort of fault that injures people or an accident or things of that sort. Quality of a product, that can have a real interesting sort of snowballing effect if you do not put the appropriate effort into understanding why the quality of your product is important. Maybe not just where you're sitting at, but how it works itself down the line.*

Another participant, a 28 year old female civil engineer with six years of work experience, further explained the role of empathy and care in design optimization, specifically in terms of going beyond standards:

> *Maybe we don't even need to put in sustainable features or environmentally friendly features because it's not a requirement. It's not something that would go into a cut and dry transportation project, but because we feel it's important as a company, and because we care about it, we will pursue that and spend that time*

*and those resources to put the extra effort into the plan. It's not required, it's not necessary, but it's important to us so we do it.*

***Theme A3: Helping others***

This theme suggests that empathy and care entail helping and serving others, generally based off an altruistic inclination to help others with no specific interest in oneself. This motivation may lead one to deliver sound, just, and sustainable engineering solutions. A 63 year old male astronautical engineer, with 45 years of experience explains within the context of engineering, "We build things in a world that really help people. That's what engineering is about, and that is an expression of care, as we build habitations and clean water systems and medical systems and devices."

**Category B: Personal outcomes**

The focus of the themes fitting within this category is on what being empathic or caring may generate for the individual in terms of understanding another or others who are central stakeholders within engineering practice. The three themes fitting this category included (a) understanding others, (b) broader impact awareness, and (c) broadening one's own perspective.

***Theme B1: Understanding others***

The core tenet of this theme is that empathy and care enable effectively understanding the view or perspective of colleagues or clients, cognitively and affectively. One of the participants, a 33 year old male with 10 years of experience working as a mechanical/biomedical engineer, explained the importance of understanding the user from a business perspective:

*I don't think enough organizations attempt to understand their customer beyond just the customer needs in terms of the product. I don't think they go beyond that and try to understand the customer's emotional state, or the things that are important to them, things that are motivational to them…. when we study customers we study how they use something and what they like, things they might want to see improved, but rarely do we study what makes that person tick. Somebody might say they want a better car but I don't know how many times we go beyond that and understand, 'How do they feel about their cars?', 'Do they like good cars because of prestige or do cars make them happy because of certain things about them?'*

Overall, this theme corresponded the most with the other themes presented throughout the qualitative portion study. Interestingly, this theme was nearly always present alongside the "meeting needs of others" theme. This suggests that practicing engineers see empathy and care as not stopping at understanding, but using this understanding to form and implement a solution based off this newfound understanding. This interpretation aligns with the themes generated from the *conceptualization*-related research question findings, where the combined empathy/care construct entails acting based off one's other-centric understanding.

***Theme B2: Broader impact awareness***

This theme indicates that empathy and care enable engineers to realize the broader impact of their engineering decisions. Further, participants generally tied this realization with eventual implementation of positive, socially just, and sustainable engineering solutions. A 47 year old male in Civil Engineering explained, "Often we [engineers] do work that's impacting society and we want to make sure we understand stakeholders" and that when such interactions "have higher quality of empathy" they add greater "value for the client". Oftentimes, participants discussed the broader impact of the engineering decisions within the context of safety. One of the participants who worked on the Boeing 787 explained:

> *When the 787 had the wing-to-body joint problems, when that first appeared in tests, even though that airplane was behind schedule and overrunning in cost, [there] was an immediate decision on the part of the company management to stop everything and make sure that that airplane was going to be safe before we ever put it into the flying public… It wasn't like they debated whether the business pressures or safety was going to be the premier effort. The decision was very rapid that safety is first. So, I think that's part of caring.*

***Theme B3: Broadening one's own perspective***

This theme suggests that, within engineering, empathy and care enables one to broader his or her own perspective by internalizing another's perspective, be it a customer, colleague, boss, or another stakeholder. This process leads to the altercation of the engineer's approach to a problem, specifically a reorientation towards ensuring the design is acceptable according to engineer's understanding of another's perspective. One of the participants, a 67 year old male chemical engineer with 44 years of work experience, explained, "You got to be able to know your audience, care about what their interests are, understand what you're trying to present from the perspective of the audience, not your perspective, and act accordingly." A second participant, a 31 year old, female, mechanical/electrical engineer with six years of work experience, further explained, "If you understand the differences in the gaps and how you perceive people and how they perceive you then you can close that gap because you know that it exists. So you can start to alter your behavior."

**Category C: Relational outcomes**

The themes fitting this category refer to interpersonal or relational skills improved as a result of being empathic or caring. The four underlying themes, in order of prevalence, include (a) building relationships, trust, and respect, (b) teamwork and solidarity, (c) effectively communicating and interacting, and (d) managing and leading others.

***Theme C1: Building relationships, trust, and respect***

This initial theme indicates that empathy and care enable engineers to develop meaningful relationships with others. Furthermore, in the experience of the interviewees, empathic and caring engineers are more likely to develop a sense of rapport, mutual trust, and respect with others. A female participant in electrical and computer engineering put it simply, "You can't have a good team that keeps working together for a long time if you don't care about each other." A second participant, a 37 year old male in construction engineering management with 15 years of work experience, explained in detail:

> *…it is all about relationships anymore. The industry has changed to the point it's not just a hard bid, or how much you know, or how good you are. It's truly, "How good are the relationships that you have with those individuals?", "Do they think*

*you care?", "Do you understand them?", "Do you understand their makeup?" As an engineer, the success for most of the successful engineers and as I've moved up project managers, and project executive and whatnot, it's how can you take on that role and relate to those individuals that are in the decision making process.*

***Theme C2: Teamwork and solidarity***

The second theme fitting this category suggests that empathy and care enable engineers working in team environments to develop a sense of solidarity, thereby increasing the effectiveness of collaboration amongst a group of colleagues. One of the participants, a 63 year old engineer with 40 years of experience in astronautical engineering explained, "99% of us work with other people and at the end of the day empathy and caring help provide the foundation of how well you do or do not work with other people." A female working in electrical and computer engineering with 36 years of experience further explained:

*One person, by themselves, isn't as good as if you have a team of people trying to solve a problem. The team will come up with a better answer than any individual could have come up with, and when you have a team that cares about each other and shows empathy for each other and, and then they get to know each other and they like each other and they respect each other, that team is going to really do a lot more. They're going to be more creative because they're bouncing ideas off of each other. I think it's harder to have synergy work if you don't have some empathy and caring going on because you won't be listening to each other.*

***Theme C3: Effectively communicating and interacting***

The third theme pertaining to this category indicates that empathy and care enable engineers to effectively communicate with others. These skills or traits allow engineers to be effective on both sides of a two-way conversation (e.g. listening and speaking). As an example, empathy and care are helpful for engineers who communicate via formal presentations (written or oral) insofar as they enable the engineer to internalize the perspective of the intended audience and modify their communicative approach accordingly. Often, the participants suggested that empathy and care will help engineers *really* listen, as the following participant, a 31 year old mechanical/electrical female engineer with six years of work experience, explained:

> *The advice that I give a lot of people is to actually listen. And when you exhibit the emotion of listening people really think that what they're saying matters and it draws them more towards you and they're like, "This is somebody that I… that really cares about what I have to say, and who's really going to help me get to the next level." So I think that the more that I learn to listen to people the easier it is for me.*

***Theme C4: Managing and leading others***

This theme indicates that empathy and care are necessary in order to successfully manage a project. In particular, empathy enables a manger to position the people working on a project in situations or work environments where they will thrive. One participant, a 67 year old male working in chemical engineering, explained:

*An example of where empathy is present is in situations where you are looking at how you're going to run a job, organize a job, etcetera. And you're thinking about which people, what people skills will best apply for that position. Let me give you an example of that. Some people are really excellent in doing design work. Other people are much better in the field but have very poor skills as far as doing design work. And then finally there are some examples where people have brilliant ability to do things technically but have no people skills. So in each of those cases you're going to use the people where their skills best apply.*

This theme was closely aligned with the theme "building relationships". A 55 year old male, chemical engineer by training who now works across multiple engineering disciplines and has 28 years of work experience, explained this as follows:

*The more you have and the better you are able to use empathy and care and be able to negotiate relationships will determine how far you will go within my discipline. As far as construction engineering and management, I can only move up as far as I can in a company by the relationships and my ability to build relationships.*

**Category D: Broader ideas**

Themes fitting this category were primarily 'big picture 'ideas, encapsulating or relating to all other themes. As a result, the inter-relation between these themes is probably the largest amongst all categories. The three themes fitting this category included (a) the necessity of empathy and care within engineering practice, (b) the value of empathy and care being context-dependent, and (c) overall, engineering practitioners tend to undervalue empathy and care.

***Theme D1: Necessary skills***

The participants in this study indicated that in order to thrive as an engineer one must have the capacity to be empathetic and caring, specifically along the aforementioned themes. Most prominently, the participants suggested empathy and care are necessary in order to understand and meet the needs of others, but participants also considered these skills necessary for leading and managing others, working in teams, and communicating and listening. One of the participants, a chemical engineer by training working as a consultant at the time of the interview, explained:

> *If you really want to develop a product or a service that's going to be successful you're really going to need to be empathetic or caring. Because if you don't build something that meets your customer's needs, they're not going to buy it. And if you don't care about the long-term impact, they may buy it once, but they're not going to buy it again.*

This theme also suggests that empathy and care are necessary in order that engineers will be conscious of and concerned with their impact on other people and the planet. One of the participants suggested that if one were lacking the capacity to empathize or care for others or the world, he or she would not be motivated to stick with engineering as their profession for their whole career. She explains:

> *With time I think engineers who are exposed to the issues of the world and see the effect of their work on people and the environment. I think with more time they*

*become more sensitized to it. I also think that there is a filtering process. I think those people that got into this profession because they wanted to make a difference and are making a difference are sticking with it. So I think it is a little bit of a filtering process and a little bit of a growth process.*

***Theme D2: Context dependence***

The importance or existence of empathy and care within a given job or work environment depends largely on the culture of the company one works for, specifically, how welcoming of an atmosphere is it for empathy and care. A 28 year old female, civil engineer, with six years of work experience, explained as follows:

*If your company is just cracking the whip, like get it done like workhorses, you're not even going to even have the option to take that extra care for a project. Because you just have to get it done as quickly as possible… I think it's got to be important to the company and then led by example and encouraged from the top down to spend that extra time, and to think of things more outside of just getting the product out at the end of the day.*

***Theme D3: Undervalued dispositions***

According to the participants, within engineering practice, empathy and care tend to be overlooked or undervalued. However, the level of value placed on these dispositions varies from workplace to workplace. A 67 year old male chemical engineer with 44 years of work experience suggested perhaps practitioners undervalue empathy and care is simply because these phenomena are not on the “radar”. He explained:

*You know the difference between being moral, immoral, and amoral? Moral, of course, is doing things that are morally right. Immoral is doing things that are morally wrong. Amoral is where you don't know. You have no, it's not on your radar screen. You're not thinking about morality. I think about half the engineers that I work with, frankly, and it's not just Chemical Engineers but all engineers, can fall into a trap of being so wrapped up in whatever the technical issue is that they're, they're empathy and caring is not, it's beside the point. It's not one of the, it's not one of the goals of the project.*

## PHASE 3.2: QUANTITATIVE METHODS AND RESULTS

The quantitative portion seeks to address the following research questions: (1) "What is the underlying factor structure of the empathy and care survey?" (2) "To what extent does empathy and care exist within engineers' practice?" and (3) "To what extent are empathy and care important to engineers' practice?" We use exploratory factor analysis to define the factor structure, and we use this structure to address research questions two and three. Secondary research questions include: (a) "Are their gender differences along the survey's factor structure?" and (b) "How do respondents compare based on their level of experience within engineering?"

As a research team, we designed a survey based off our previous research findings (Hess et al., 2012; Strobel et al., 2013) but *not* based off of the results from the qualitative analysis described in Phase 3.1. We disseminated the survey to engineering alumni from a large Mid-Western university. As such, as a proxy-indicator of empathy and care within engineering, the survey is limited in its scope as it provides insight into the perceptions of individual engineering graduates from this single Midwestern engineering university. However, the large sample offsets some of this concern, as in total, we received 1574 useful responses.

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. In order to explore the effects of gender and the effects of total number of years work experience on participants' perception of the presence and importance of empathy and care in engineering work and practice, we performed Kruskal-Wallis test and Wilcoxon-Mann-Whitney test on the dataset using the derived factor structure. These tests were chosen as they are specifically designed for data which violate normality assumptions, as the quantitative data did (McCrum-Gardner, 2008).

**Empathy and Care Survey Design**

We designed the survey in this study using themes derived from our previous studies (Hess et al., 2012; Strobel et al., 2013; Strobel et al., 2011). In Appendix B we have included the 37-items from the survey. Along with the items, Appendix B includes mean and standard deviation scores on each item. 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 to the end, and 50 more participants for failing to answer six or more questions. Therefore, we did not remove participants that neglected to answer one to five questions. After removing these 574 participants, 1574 participants remained for exploratory factor analysis.

**Exploratory Factor Analysis**

Factor analysis is used as a data reduction technique and for the development of scales (Pallant, 2007, p. 179). We used exploratory factor analysis before outputting individual item descriptive statistics in order to discover the primary interrelationships among survey questions. When performing exploratory factor analysis we excluded questions 13-16 because these questions were on a scale of 1-100 whereas all other questions varied on a Likert scale of 1-6 (see Appendix B). We separately examined and analyzed Questions 13-16.

We subjected the 33 items from the survey set on six-point Likert scales 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. The 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 (Kaiser, 1974), and Barlett's Test of Spherity (Bartlett, 1954) yielded a significance value of 0.000 supporting factorability of the correlation matrix.

Principal component analysis (PCA), a type of exploratory factor analysis, revealed the presence of 8 components with eigenvalues exceeding 1. The cumulative explanation of the total variance increased just slightly beyond an additional 1% for factors 5, 6, 7, and 8 (see Table 3.4).

**Table 3.4**: *Principal component analysis of the empathy and care survey items*

| Component | Initial Eigenvalues | | |
|---|---|---|---|
| | Total | % of Variance Explained | 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" (Ed & Psych Associates, 2011) inputting 33 variables x 1574 respondents. Table 3.5 shows the criterion values generated from this parallel analysis. Comparing these to the actual eigenvalues from PCA showed the number of retainable factors by examining when the actual eigenvalue became less than the criterion value. Using this rule and the output (shown in Table 3.5) indicated that the model retain six factors.

**Table 3.5**: *Eigenvalues generated from principal component analysis*

| Component Number | Actual Eigenvalue from PCA | Criterion value from 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** |

**Table 3.6**: *Survey's pattern and structure matrix from PCA with oblimin rotation*

| Item | Pattern coefficients | | | | | | Structure coefficients | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | F1 | F2 | F3 | F4 | F5 | F6 | F1 | F2 | F3 | F4 | F5 | F6 |
| **Q1** | .081 | .056 | .059 | **.686** | .007 | .125 | .599 | -.177 | .044 | .442 | .040 | -.084 |
| **Q2** | .017 | -.156 | .019 | **.637** | .008 | -.096 | .514 | -.324 | -.076 | .249 | .101 | -.175 |
| **Q3** | .012 | -.070 | .012 | **.835** | -.052 | -.015 | .606 | -.371 | -.030 | .435 | .057 | -.185 |
| **Q4** | -.051 | -.060 | .020 | **.824** | -.035 | .007 | .570 | -.386 | .006 | .437 | .075 | -.155 |
| **Q5** | -.008 | **-.803** | .091 | .028 | .024 | -.004 | .585 | -.406 | -.183 | -.401 | -.044 | .092 |
| **Q6** | .033 | **-.798** | -.010 | .074 | -.041 | .029 | .565 | -.426 | -.249 | -.333 | -.111 | .103 |
| **Q7** | .011 | -.193 | -.037 | **.611** | -.056 | .121 | .562 | -.340 | -.059 | .304 | -.030 | -.021 |
| **Q8** | -.031 | **-.682** | -.067 | .176 | -.040 | .079 | .503 | -.441 | -.213 | -.187 | -.093 | .123 |
| **Q9** | .012 | -.026 | .217 | .140 | .103 | .176 | .399 | .007 | .159 | .064 | .042 | .073 |
| **Q10** | .051 | **-.574** | .093 | .165 | .182 | .012 | .645 | -.265 | -.147 | -.216 | .111 | .074 |
| **Q11** | .141 | **-.373** | .032 | .305 | .296 | -.087 | .628 | -.153 | -.196 | -.061 | .257 | -.022 |
| **Q12** | .023 | **-.551** | .124 | .198 | .228 | -.027 | .652 | -.268 | -.124 | -.209 | .173 | .048 |
| **Q17** | .143 | .010 | .302 | .224 | **-.442** | .137 | .368 | -.091 | .204 | .126 | -.413 | -.157 |
| **Q18** | .005 | .011 | .059 | .006 | **.690** | .203 | .395 | .230 | .036 | .021 | .514 | .300 |
| **Q19** | .174 | -.102 | .020 | .002 | **.625** | .183 | .523 | .239 | -.087 | -.029 | .423 | .265 |
| **Q20** | .104 | -.062 | .273 | -.044 | **.451** | -.152 | .361 | .183 | .039 | -.198 | .401 | -.045 |
| **Q21** | .108 | -.024 | -.086 | .031 | .075 | **.769** | .467 | .118 | .087 | .272 | -.212 | .536 |
| **Q22** | -.115 | -.064 | .134 | -.012 | .028 | **.781** | .446 | .007 | .307 | .180 | -.221 | .539 |
| **Q23** | **.410** | .014 | .085 | .108 | .066 | .362 | .623 | .243 | -.015 | .161 | -.127 | .149 |
| **Q24** | **.581** | -.061 | .040 | .075 | .002 | .235 | .651 | .272 | -.159 | .079 | -.182 | .044 |
| **Q25** | **.705** | .111 | .003 | .066 | .104 | .102 | .570 | .441 | -.220 | .119 | -.062 | -.056 |
| **Q26** | **.690** | .143 | .004 | .215 | .153 | -.084 | .567 | .388 | -.258 | .155 | .065 | -.200 |
| **Q27** | **.648** | .193 | .073 | .246 | .134 | -.113 | .552 | .378 | -.190 | .171 | .076 | -.245 |
| **Q28** | **.597** | -.034 | .050 | .112 | .143 | .148 | .684 | .313 | -.184 | .075 | -.031 | .006 |
| **Q29** | **.780** | -.184 | -.025 | -.157 | -.113 | -.011 | .498 | .342 | -.364 | -.169 | -.275 | -.109 |
| **Q30** | **.691** | -.303 | .040 | -.204 | -.089 | -.068 | .504 | .262 | -.340 | -.290 | -.235 | -.115 |
| **Q31** | .310 | **-.420** | .200 | -.076 | -.078 | .151 | .617 | -.008 | -.074 | -.245 | -.219 | .059 |
| **Q32** | .056 | -.035 | **.718** | .063 | -.073 | .063 | .610 | .044 | .440 | -.137 | -.084 | -.147 |
| **Q33** | -.018 | -.237 | **.723** | -.056 | -.006 | .022 | .609 | -.034 | .398 | -.321 | -.032 | -.094 |
| **Q34** | .052 | .122 | **.591** | .079 | .018 | .269 | .569 | .149 | .454 | .042 | -.060 | .019 |
| **Q35** | .026 | -.047 | **.751** | -.001 | .041 | .073 | .623 | .085 | .464 | -.191 | .006 | -.098 |
| **Q36** | .085 | -.021 | **.650** | .115 | .114 | -.010 | .642 | .087 | .356 | -.118 | .100 | -.151 |
| **Q37** | -.072 | .048 | **.698** | -.052 | .008 | -.112 | .316 | .069 | .453 | -.218 | .060 | -.206 |

Next, we analyzed the component matrix to decide if we should keep six or less factors. Starting with six factors and examining the output, many items loaded onto the first four potential factors and only four and three items on the $5^{th}$ and $6^{th}$ factors, respectively. 12 items were loaded onto Factor 2, eight items onto Factors 3 and 4, four items on Factor 5, and only 2 items on Factor 6. This suggested that we ought to reduce the structure to four or five factors. The four-factor solution explained 49.2% of the variance, the five-factor solution explained 53.2%., and the six-factor solution explained 56.7%.

As the 6 factor solution still only explained 56.7% of the variance, we chose to retain the 6-factor solution. 50% has been depicted as the lower threshold for acceptability when seeking to explain the variance within a survey through survey constructs, although many studies report as high as 75% should be the minimum threshold (Beavers et al., 2013). An oblimin rotation assisted the 6-component output interpretation. This output showed numerous strong loadings onto each of the six components, which added support to this structure. Table 3.6 shows the resulting pattern matrix and structure matrix for each item. We considered pattern coefficients with loadings greater than .4 as retainable on a given factor, and when combining constructs we paired items with the factor to which they most strongly loaded.

**Derived Factor Structure of the Empathy and Care Survey**

The six factors derived from the exploratory factor analysis were found to be internally consistent, although the fifth and sixth factors were only minimally acceptable (DeVellis, 2011). The authors named these factors by examining the items mapped to each factor, including the question prompt and the specific questions themselves. Through dialogue and extensive conversation, the authors named what they believed each factor was measuring, as follows:

1. The **existence** of empathy and care within engineering work and practice
2. **Social** implications of empathy and care guiding engineering practice
3. **Improvements** in engineering outcomes when empathy and care drive practice
4. The importance of empathy and care in people **relational** aspects of engineering work
5. The extent to which empathy and care are **learnable**
6. The **necessity** of being empathic/caring to succeed as an engineer

Table 3.7 shows the items paired to each of these factors and their reliability. The bold items included in Table 3.6 (with a few changes implemented to increase the reliability of the derived factor structures) formed the six-factor solution. For example, Questions 17 loaded *negatively* onto factor five but still decreased its reliability significantly when we measured the internal-consistency of the collection of items (Cronbach's Alpha increased from 0.528 to 0.615 by removing this item). Each of the first four factors was in the range of good to excellent, suggesting that the factors were internally consistent (Kline, 2000), whereas Factors 5 and 6 were minimally reliable, being in the 0.6-0.7 range (DeVellis, 2011).

**Table 3.7**: *Derived factor structure from empathy and care survey*

| Factor Number | Factor Name | Items Paired to Factor† | Factor Reliability |
|---|---|---|---|
| 1 | Current **Existence** | 23, 24, 25, 26, 27, 28, 29, 30 | 0.858 |
| 2 | **Social** implications | 5, 6, 8, 10, 11, 12, 31 | 0.858 |
| 3 | **Outcome** improvements | 32, 33, 34, 35, 36, 37 | 0.833 |
| 4 | **Relational** Importance | 1, 2, 3, 4, 7 | 0.837 |
| 5 | **Learnability** | 18, 19, 20 | 0.614* |
| 6 | Level of **Necessity** | 21, 22 | 0.679* |

†See Appendix B for item descriptions
*Factor is only minimally acceptable

**Quantitative Comparisons using the Factor-Structure**

After performing the exploratory factor analysis, we removed participants who did not provide information on gender or years of work experience, along with those who did not have any experience working in engineering after graduation. In this section, we used the 1481 remaining respondents and the survey's factor structure derived in the previous section to compare (a) factors against one another to depict which factors were most favorable from the perspectives of this study's participants, (b) responses by years of work experience, and (c) responses by gender. We re-emphasize the conceptualization of empathy and care derived from the qualitative analysis, where for the participants the combined construct of empathy and care included both (a) understanding others both cognitively and emotively, alongside (b) acting on an understanding or internalization of the others' thoughts or feelings.

The gender distribution of the 1481 respondents includes 1198 males (81%) and 283 females (19%). We asked participants which engineering degree they received and in which discipline(s) they are currently working. Figure 3.4 shows the engineering degree participants graduated with from a Mid-Western University alongside the current profession(s) of survey participants at the time of the survey. For each question we allowed participants to select multiple disciplines. As a result, many more respondents selected “multi-disciplinary” engineering as their current area of work when compared to their engineering degree.

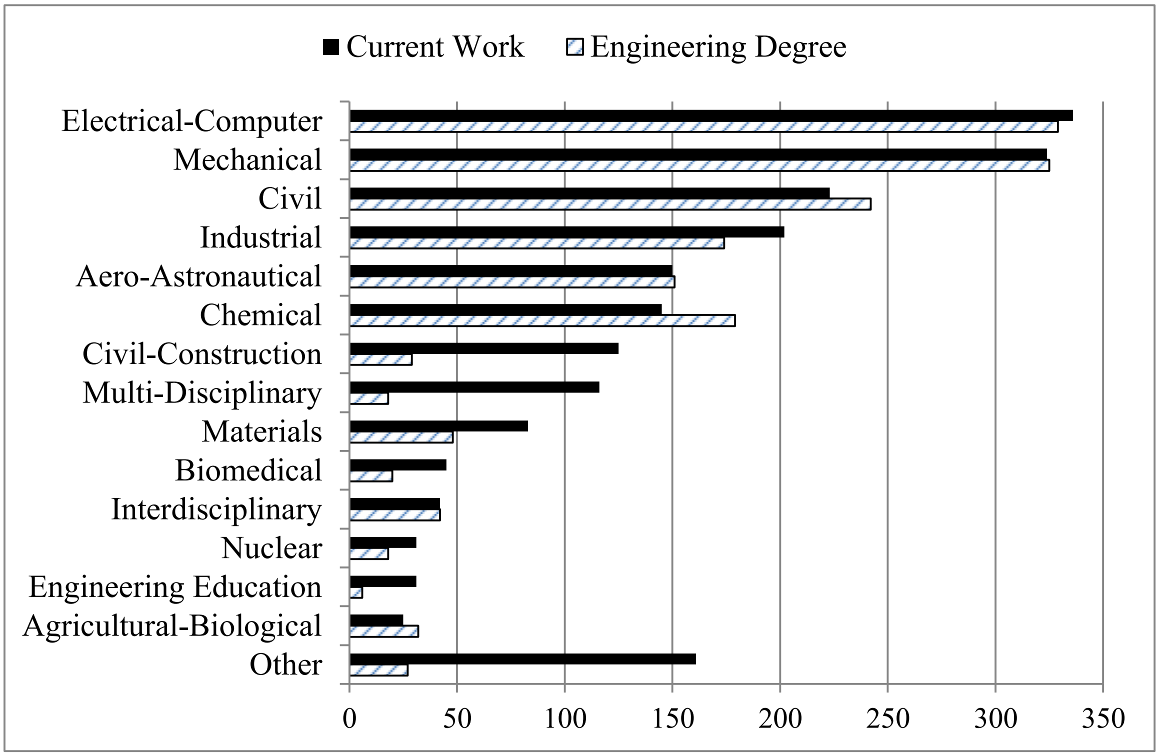


**Figure 3.4**: *Engineering practice and engineering degree of the survey participants*

Figure 3.5 shows the mean score along each factor, where factors proceed in order of highest to lowest mean scores. While Appendix B shows mean scores along each survey item, comparing trends along the derived constructs is our primary interest in this section. As Figure 3.5 shows, **relational** received the highest score and **learnable** received the lowest, which indicates participants were most in favor of the idea that empathy and care are important in relational aspects of engineering work and they were least inclined to agree that empathy and care are actually learn-able. The marked differences between the factors we called **necessity** and **existence** seem particularly noteworthy.

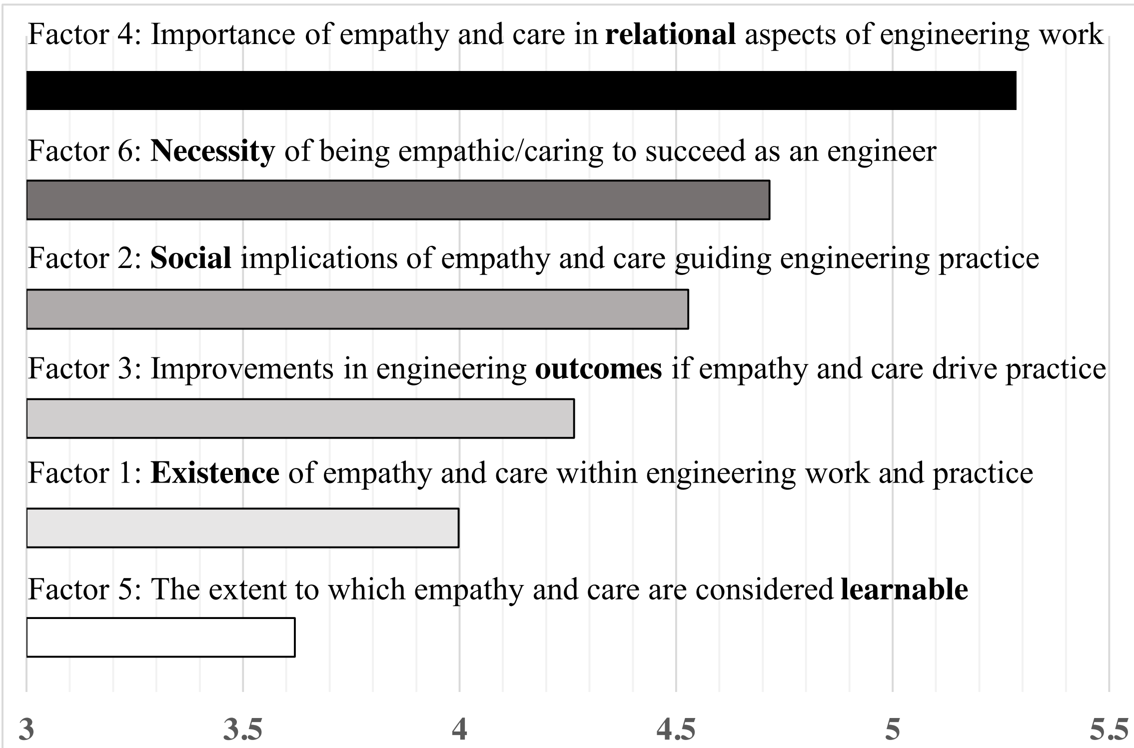


**Figure 3.5**: *Mean scores across survey factors (responses were along a 6-point Likert scale)*

In order to identify if there were significant differences in favorability towards any two factors amongst participants, and as normality assumptions were violated as indicated by Shapiro-Wilks coefficients ($p < .001$; data was skewed to the left along each factor), we performed a related samples Wilcoxon signed rank tests on the data set. The Wilcoxon mean score for each factor obtained from the survey showed that each higherranked factor was significantly greater than each factor below it as displayed in Figure 3.5 ($p < .05$).

In Questions 13 and 14, we asked participants to rate how important empathy and care were for them "as an individual" and in Questions 15 and 16, we asked participants to rate how important empathy and care were for them "as an engineer", each on a sliding scale ranging from 1 to 100. We compared the scores of the combined responses of 13/14 ($\alpha$=0.793) and 15/16 ($\alpha$=0.798) using Wilcoxon-Mann-Whitney test. Table 3.8 shows participants considered empathy and care to be more important for them as an "individual" than as an "engineer" ($p < 0.001$).

**Table 3.8**: *Wilcoxon-Mann-Whitney test results comparing Q13/14 and Q15/16*

| Question | Wilcoxon Mean Score |
|---|---|
| Q13/14 – Importance of empathy and care "as an individual" | 1662.0 |
| Q15/16 – Importance of empathy and care "as an engineer" | 1282.4 |

**Group Comparisons**

In order to explore how males versus females and engineers with varying years of work experience responded to these factors, we performed Wilcoxon Mann-Whitney and Kruskal-Wallis tests on each of the factors. These tests start with the assumption that participants in different groups will not score significantly different along each factor. We used non-parametric tests in both cases because the data was approximately non-normal.

**Comparing survey factor responses by gender**

To explore whether females and males responded to the factors differently, we analyze the data using Wilcoxon-Mann-Whitney test, again starting with the assumption that males and females would not rank significantly different on each factor. Table 3.9 provides descriptive statistics for scores along each of the 6 factors underlying the survey divided by gender.

**Table 3.9**: *Descriptive statistics of survey factors by gender*

| Factor Number | Factor Name | Males (n = 1198) | | Females (n = 283) | |
|---|---|---|---|---|---|
| | | **Mean** | **σ** | **Mean** | **σ** |
| 1 | Current Existence | 4.02 | .91 | 3.90 | .93 |
| 2 | Social implications | 4.56 | .95 | 4.40 | 1.03 |
| 3 | Outcome improvements | 4.26 | .96 | 4.29 | .93 |
| 4 | Relational Improvements | 5.28 | .69 | 5.32 | .62 |
| 5 | Learnable | 3.68 | 1.00 | 3.38 | 1.02 |
| 6 | Level of Necessity | 4.69 | 1.15 | 4.81 | 1.08 |

Note: Mean scores correspond to a 6-point Likert scale

As Table 3.10 shows, Factors 1, 2, and 5 showed significant gender effects ($p < .05$), indicating that males were significantly more likely to perceive empathy and care as **existing** in their work, having profound **social** implications, and **learnable** when compared to the female participants. No significant difference was found between male and female respondents along potential **outcomes** (Factor 3, p = 0.69), **relational** aspects (Factor 4, p = 0.47), or **necessity** (Factor 6, p = 0.21). In each of these latter 3 cases females scored slightly higher than males.

**Table 3.10**: *Wilcoxon mean scores for survey factors classified by gender*

| Gender | F1: Existence | F2: Social | F3: Outcomes | F4: Relational | F5: Learnable | F6: Necessity |
|---|---|---|---|---|---|---|
| Male | 729.7* | 721.6* | 730.9 | 730.1 | 763.8* | 734.3 |
| Female | 673.8 | 662.6 | 742.0 | 750.4 | 639.6 | 769.4 |

*Males scored significantly higher than females ($p < .05$)

To test whether gender was a significant variable in determining how important practicing engineers' indicated empathy and care was for them 'as an engineer', we performed independent samples Mann-Whitney-U tests on the dataset. There was no significant gender difference (p = 0.66), although as Table 3.11 shows, males scored slightly higher than females along the combined Q15/16 measure.

**Table 3.11**: *Wilcoxon-Mann-Whitney Test results comparing gender responses to Q15/16*

| Gender | Q15/16 Importance "as an engineer" |
|---|---|
| Male | 737.3 |
| Female | 725.3 |

**Comparing survey factor responses by experience**

We stratified participants into four groups according to years of work experience based on the number of years they had worked in engineering. Table 3.12 shows this group division and distribution.

**Table 3.12**: *Participants' demographic distribution by years of work experience*

| Years of experience in engineering | Group | Number of participants | Relative percentage of sample |
|---|---|---|---|
| 0 – 5 | Beginner | 126 | 8.5% |
| 6 – 20 | Experienced | 530 | 35.8% |
| 21 – 40 | Advanced | 648 | 43.8% |
| Above 40 | Expert | 177 | 12% |

To test whether years of engineering work experience was a significant variable along any of the factors, we performed independent samples Kruskal-Wallis tests for each factor. The null hypothesis for each was that practicing engineers' years of work experience would not be a significant factor. We found that work experience was always a significant variable ($p < .0001$ along each factor). Table 3.13 shows the *expert* group and *advanced* group consistently rated highest and second highest along each factor, respectively. This data suggests that with increased work experience, practicing engineers become more favorable towards empathy and care along all aspects of the survey's factor structure. However, the "beginner" group scored slightly higher than the "experienced" group along three of the factors.

**Table 3.13**: *Kruskal Wallis Scores from survey factors classified by years of experience*

| Work Experience | F1: Existence | F2: Social | F3: Outcomes | F4: Relational | F5: Learnable | F6: Necessity |
|---|---|---|---|---|---|---|
| Beginner | 674.6 | 646.6 | 715.2 | 661.7 | 642.6 | 622.0 |
| Experienced | 654.9 | 629.0 | 689.5 | 666.7 | 661.7 | 716.5 |
| Advanced | 742.4 | 751.8 | 749.8 | 767.0 | 789.4 | 758.7 |
| Expert | 867.9 | 860.4 | 817.7 | 852.6 | 864.2 | 834.2 |

**p < .0001 for each factor*

To test whether years of work experience was a significant variable in how important practicing engineers' indicated empathy and care was for them "as an engineer", we performed independent samples Kruskal-Wallis tests on Q15/16 and again found the effect of work experience to be significant ($p < 0.001$). Table 3.14 shows the *expert* group and *advanced* group rated highest and second highest in the importance of empathy and care for them as an engineer, but the *beginner* group scored slightly higher than the *experienced* group.

**Table 3.14**: *Kruskal-Wallis Test results comparing the effect of experience on Q15/16*

| **Engineering Work Experience** | **Perceived importance of empathy and care *"as an engineer"*** |
|---|---|
| Beginner (0-5 years) | 680.8 |
| Experienced (6-20 years) | 652.4 |
| Advanced (21-40 years) | 779.6 |
| Expert (more than 40 years) | 857.2 |

PHASE 3.3: COMBINED DATA INTERPRETATION AND DISCUSSION

In this section, we combine results from the qualitative and quantitative phases of this study to holistically explore how the practicing engineers who participated in this study perceived empathy and care within their own practice of engineering, along with broader implications in the practice of engineering more generally.

**Empathy and Care within Engineering**

As the conceptual themes showed, in the experience of practicing engineers, cognition, affect, and action are all important for the paired construct, empathy and care. When situated within engineering practice, empathy and care closely resemble M. H. Davis's (1996) functional model of empathy, where intrapersonal outcomes (e.g. understanding another) lead directly to interpersonal outcomes (e.g. helping behavior). Interestingly, three of the four categories encompassing the phenomenological themes emphasized just this: *outcomes*. Perhaps this was due to the framing of the interview protocol, but the participants spent the majority of the interviews talking about what empathy and care *do* within the context of engineering as opposed to how these phenomena operate or developed psychologically. For example, at the start of an interview, when we would ask conceptual questions, many participants would venture directly into a vivid example from their experience where empathy and care played a direct role. This corroborates findings regarding the 'utilitarian' perspectives derived from practicing engineers' open responses in Chapter 2.

As the phenomenological themes indicated, empathic and caring design outcomes require careful consideration of the context and logically sound and ethical implementation of the chosen solution in order to minimize the potential negative effects of an engineering decision. Empathic and caring engineers use their knowledge of others (human or non-human) and alter their behavior accordingly. They seek to understand users' needs and implement that knowledge within their own work. They are conscious of the broader potential impact of their engineering decisions and strive to ensure their decisions are the *best* given their knowledge of that potential effect on others. Empathy and care allow engineers to make informed decisions within a social context, where the perspectives of the relevant stakeholders are embedded within the engineers' decision-making processes. They also allow engineers to build and maintain strong interpersonal relationships with others, be those relationships with colleagues, clients, employers, or bosses.

**Emphasis on Empathic Design**

The most pervasive theme from the phenomenological analysis was **meeting users' needs**. Likewise, from the survey, the highest mean score was to Question 2, inquiring about the importance of empathy and care in meeting a client's needs. These themes align with the nuances depicted throughout the emerging literature on empathic design (Leonard & Rayport, 1997; Mattelmäki, Vaajakallio, & Koskinen, 2014; Postma, Zwartkruis-Pelgrim, Daemen, & Du, 2012).

As an example, Kouprie and Sleeswijk Visser (2009) suggested contemporary usage of the term 'empathic design' puts multiple spins on the core construct, empathy. On one hand, it sees empathy as an **inherent quality** in doing design work which requires the designer to relate to the user both intellectually and emotionally and to not judge the correctness of the user's perspective. Second, it sees empathy as the **ability** and **willingness** to identify with others, cognitively and emotively. Lastly, it sees empathy as a **technique** which involves communicating with the stakeholder and may involve taking their viewpoint. Paired with care, we propose that an empathic design proceeds non-linearly through a series of steps that include first **relating** to the potential users, second **understanding** their needs *holistically*, third **developing** a solution to meet the identified needs, fourth **implementing** a solution, and lastly **revising** a solution throughout its implementation by gathering feedback ethnographically or verbally from the users. The emergent empathic design model described by Fila and Hess (2014) highlights these components, including a focus on empathic techniques designers may use to develop empathic understanding (e.g. observation, interaction).

**Years of Work Experience as a Significant Variable**

The importance of empathy and care to practicing engineers increases with years of work experience, as shown by the quantitative results along *every* factor. One possible explanation for this may be that engineers with more experience are more likely to move into management and leadership positions, and in this study's participants' experiences, one cannot effectively manage others while lacking empathy and care. Those individuals who had advanced throughout their careers into leadership and management positions explicitly pointed to their ability to empathize or to care as what enabled them to reach that level of career advancement.

These participants suggested that if lacking empathy or care they would not have succeeded in these higher-level positions. On a related note, participants suggested they did not realize how important empathy and care were until later in their engineering careers. An explanation for these age trends then, may not be that engineers move into roles that require interpersonal competence, but rather, that engineers begin to see empathy and care as more important as they begin to frame their career goals differently. Perhaps over the course of their careers, engineers become intimately concerned with the broader impact of their engineering decisions, thereby placing a greater emphasis on helping others or building solid relationships. In support of this view, a female engineering participant suggested that the engineers with the longest lasting careers she had seen were those who continually seek to make a lasting, positive impact on people and the planet. Without that drive or disposition, this participant posited that an engineer would alter their chosen career path, ultimately moving out of engineering.

Cooper (2011) suggests that empathy increases with age for everyone, and this is because older individuals have learned more in total and have had a greater variety of life experiences than have younger individuals. Cooper's proposition is that increased knowledge and experience simultaneously increases the likelihood that one will relate to others, try to understand novel viewpoints, and thereby empathize. Contrary to Cooper's suggestion, and analogous to this study's findings, numerous studies have found empathy to decline with age (Schieman & Van Gundy, 2000), sometimes strictly along the cognitive dimension of empathy (Bailey, Henry, & Von Hippel, 2008; Orgeta & Phillips, 2008; Slessor, Phillips, & Bull, 2007), but other times along the affective dimension (Phillips, MacLean, & Allen, 2002; Ruffman, Henry, Livingstone, & Phillips, 2008). For example, Decety and Michalska (2010) compared differences in brain regions activated upon an empathic and sympathetic "pain" stimuli between adults as old as 40 and children as young as seven and found adults were less likely than children to respond affectively as a result of "reduced activity within limbic affect processing systems" with age (p. 896). Despite these numerous studies and this finding from the field of neuroscience, a 12-year longitudinal study by Grühn et al. (2008) found empathy to be relatively stable with increased age. Taken altogether, these studies suggest there is much empirical work needed to develop the best predictors of empathy gains or losses throughout one's life. Further, scholars must pay direct attention to which empathy-type they address (e.g. is their focus on cognitive, affective, or helping behavior? Decety and Micalska [2010] seemed to be analyzing empathic responding as opposed to empathic understanding).

It is important to emphasize that what we measured throughout the quantitative component of this study was practicing engineers' *perceptions* of empathy and care and not these individual's psychometric empathic or caring *tendencies*. This leaves open the research question as to the direct correlation between perception and tendency which should be the focus for future inquiry. Theoretically, the two are closely related.

**Comparing Results by Gender**

As we did not directly explore differences in qualitative themes by gender, the differences in gender from the quantitative results were particularly surprising. The non-parametric tests along the survey factors indicated that male participants scored significantly higher than female participants along the factors we called **existence** within engineering work and practice, **social** implications within engineering work, and the extent to which empathy and care were considered **learnable**. However, the female participants scored slightly higher on the remaining three factors that we labeled importance within **relational** aspects of engineering work, **necessity** to succeed as an engineer, and improved **outcomes** if empathy and care drive engineering practice. We believe we must tread lightly in our interpretation of these findings. It may be that the female participants were more stringent about what counts as empathy and care within their work environment. Or it may be that the female participants were more pessimistic about the broader landscape of empathy and care within engineering. This latter interpretation might suggest that, not including their own person, women do not see empathy and care as prominent in their colleagues' engineering ethos. This makes sense in light of the finding, when comparing male and female responses to Question 23, "*Empathy and care is present in my work as engineer*," women scored higher than males ($\mu_{\text{Q23, females}} = 4.84$; $\mu_{\text{Q23, males}} = 4.70$).

As stated, we did not structure the qualitative portion of this study to systematically explore nuances based on gender, but in a few instances the topic of gender differences did arise, most notably in the interviews with female participants. We believe it is plausible that the female participants' views were suppressed based off the sampling and analysis strategy employed by the authors, as we had nearly half as many female interviewees (n=9) compared to males (n=16). Revisiting female responses ad hoc paints a slightly different picture of the phenomenological themes developed, as the majority of the female participants made some reference to differences in approaching problems based off gender *without* the interviewer ever priming the topic. As one participant, a 31 year old engineering working in Mechanical and Electrical Engineering, noted:

> *On being a female engineer I put different perspective on it and I treat relationships differently than my male counterparts would treat their relationships. So I think it's a lot easier for me to show caring or empathy towards others in my career path than it would be for them.*

Another participant, a 54 year old female engineering working in Chemical Engineering, stated:

> *I think that a lot of men, when you say empathy and care, that is all female stuff. And they don't necessarily want to. You say those words and they think that you're all going soft and it does not belong in engineering.*

Throughout the United States, males are represented much more widely throughout engineering than women (Falkenheim & Burrelli, 2012). Infrequently explored is how this may lead to a lack of inclusivity for divergent value systems such as femininity within the U.S. Engineering Education system. Foor, Walden, Shehab, and Trytten (2013) found that two separate female engineering students working alongside solely male colleagues faced numerous challenges arising from stereotyped gender roles and work schemas. The authors concluded, “The lack of women on this SELECT is not due to a lack of interest but to structural and cultural factors that are far from inclusive” (p. 354). However, it has been reported that female students may leave engineering out of a desire to help others, or towards a degree where they envision a “social good” component missing from engineering (Borrego, Padilla, Zhang, Ohland, & Anderson, 2005; Sax, 1994).

Taken together, these findings may indicate that women who persist in engineering are those who either already have or are able to find appropriate support structures (e.g. SWE, mentioned by multiple of the participants), or perhaps these women are willing and able to be enculturated into and thereby adopt the dominant image ethos of engineering. A separate interpretation would be that altruistically motivated females who remain in engineering are cognitively aware of the social good they may achieve through their work as an engineer. This may indicated that to attract a large population of females to engineering, we may we need to change not only the dominant images of engineering by ‘changing the conversation’ (NAE, 2008), but more importantly, the core components of the engineering worldview. This would entail radical realignment of the core values of engineering with humanitarian and sustainability-related ethos, change which is difficult to realize (Splitt, 2003) but imperative for radical institutional transformation (Matusovich, Paretti, McNair, & Hixson, 2014; Matutinovic, 2007).

As a disclaimer of sorts, Question 37 (If empathy and care are effectively incorporated into engineering… Engineering will attract more females) from the survey showed virtually no difference when comparing male and female responses, and both groups scored only slightly positively, just above a neutral score of 3.5 (the mean score for males was 3.58 and for females was 3.61). However, in direct contrast, one of the male participants stated:

> *One of the real challenges we have in this profession is attracting more women. And I think strides have been made in that and a lot of the strides I'm aware of and things I've done, advisory groups and things like that, is helping portray engineering as caring. And not just kind of a bunch of people that sit around and care about each other, but like I said, people are building systems. Clean water systems and help systems that help people. And that as an expression of caring I think is very attractive to women. And that's a way to recruit and maintain more and more women in our profession, which is extremely important.*

**Empathy and Care as Necessary to Succeed within Engineering**

In the experience of this study's participants, empathy and care are necessary skills to thrive as an engineer, although within some aspects of engineering work empathy and care are less important. The idea that these skills are necessary was present in the majority of interviews, whereas the notion that it depends on the type of work was present in roughly half of the interviews. The survey results validate the idea that empathy and care are necessary in engineering, as nearly 70 percent of the participants either disagreed or strongly disagreed to the claim "*it is not necessary to be empathetic or caring to be successful in engineering*".

However, as the **context-dependence** phenomenological theme indicated, there remains a question regarding where and when empathy and care are most important, and where and when they are least important for engineering practices. The factor comparisons indicated participants perceived the **relational** aspects of engineering work as the most important domain for empathy and care within engineering. In regards to design outcomes, however, many participants noted potential competitive disadvantages of being *too* empathetic or *too* caring. Participants referred to trying to perfect a design, being unwilling to take necessary risks, or not being strict enough as potential threats to the business side of engineering stemming from an overabundance of empathy and care.

In the Engineer of 2020 report the National Academy of Engineering (NAE, 2004) does not explicitly call for empathy or care to be integrated into curriculum, but they do mention several key needs related to empathy and care. For example, in an increasingly global and dynamic world, NAE suggested engineers must be capable of adapting to an ever-changing set of demands from customers. The practicing engineers interviewed in this would likely agree that empathy and care are essential to accomplish such a task. Likewise, NAE and the National Research Council (2009) defined six habits of mind as being most important to engineering. Of these six, three directly relate to empathy and care as indicated by this study's findings, which include: (1) being interdependent by leveraging perspectives and knowledge of others, (2) communicating with clarity and precision, and (3) being attentive to the ethical implications of the impacts of engineering decisions on people and the environment.

**Implications for Engineering Educators**

The findings presented in this study have indicated that engineers may be unique from the rest of the population when it comes to empathy and care with these phenomenon becoming more important to engineers as they navigate throughout their careers. However, it is important to note that what we measured was practicing engineers' perceptions and not their actual empathic tendencies. Although the majority of the participants did not regard empathy and care as learnable, this factor was weighed down by question 20, "*I learned to be more empathetic and caring during my college years".* Indeed, this question held the *only* negative mean score from the survey of the nearly 1500 participants, suggesting that the engineering education system of years past has been particularly ineffective at instilling these skills. What is more telling is that the mean score of question 18, "I believe traits associated with empathy and care can be learned", held a very positive mean score of 4.37. Therefore, it is not that these participants felt that empathy and care could not be learned, but rather that they suggested their engineering education did not promote these skills.

Much of the literature in other disciplines such as medicine, nursing and counseling suggests empathy and care and associated skills are learnable even in college and beyond (Shapiro, Morrison, & Boker, 2004). Existing strategies employed by other disciplines (and to a slight degree in engineering education) are focused on (1) strengthening Emotional Intelligence, (2) strategies to learn more about oneself with respect to others, (3) active listening and communication strategies, (4) design strategies in human-centered and user-centered design and (5) strategies or techniques, including discussion, immersion, role play, and computerized simulations (McQuiggan & Lester, 2006).

While strategies for incorporating empathy and care into engineering curricula are rudimentarily described throughout the literature (Zoltowski, Oakes & Cardella, 2012) and currently being developed (Walther, Miller, & Kellam, 2012), more research and engineering-specific training methods needs to be developed. Foor, Walden, and Trytten (2007) regarded higher education as the transmitter of "dominant culture" (p. 111). If empathy and care are important for the practice of engineering as the respondents indicated, then in order for empathy and care to become embedded within engineering, future questions which need to be addressed by engineering educators are, "To what degree are we attracting empathetic/caring individuals to engineering?", "From the perspective of individuals outside of engineering (including prospective students and their parents), is engineering perceived as an empathetic and caring discipline?", "How do we attract empathetic and caring individuals to engineering?", "If engineers need these skills and if the profession openly promotes empathy and care, would empathic and caring individuals become motivated to join the profession?", "How do we develop a welcoming and inclusive engineering culture where divergent value systems are not restricted by the dominant culture?", and "How might we develop empathy within engineering courses?"

# CONCLUSION

This study has explored practicing engineers' perceptions of the paired construct, empathy and care, within the practice of engineering. The engineering participants suggested a greater inclusion of empathy and care within the culture of engineering has the potential to improve engineering along multiple facets. Potential positive benefits ranged from enabling engineers to better understand and meet users' needs to improving the solidarity amongst engineering colleagues. The qualitative analysis indicated that the majority of the engineering participants considered the ability to be empathic and caring was necessary for career advancement or career persistence within engineering. The survey findings corroborated this finding, showing that with increased years of work experience, the perceived importance of empathy and care also increased.

Nonetheless, one of the phenomenological themes indicated that the importance or existence of empathy and care within a work setting depends on the broader culture or environment of the workplace. This suggests that integrating empathy and care into the workplace must start with the culture or upper management of the workplace, or even more broadly, the dominant images persisting throughout the culture of engineering. It also indicates that, despite the limited existing strategies for incorporating empathy into engineering curriculum, and despite the already overcrowded curriculum, there is a need for embedding empathy and care (or related skills) into engineering education.

# LIMITATIONS

Readers may justifiably question the generalizability of this study, as one may consider the participants to be products of the culture of the particular university. We believe this is not a significant limitation, as many of the participants have been out of the university for a long period of time. A separate concern may be that the participants in this study's survey are potentially those primarily interested in the subject topic, which on one hand the reader may perceive 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. Nonetheless, this study has been primarily exploratory and future studies of a confirmatory nature should follow. Furthermore, all engineering disciplines could be further broken down and investigated individually. Lastly, a study focusing solely on the empathy and care of engineers who work primarily leadership and management positions would produce interesting results to compare to the findings portrayed here.

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# CHAPTER IV

# THE DEVELOPMENT OF PERSPECTIVE-TAKING TENDENCIES: A MIXED METHODS EXPLORATION WITHIN AN ENGINEERING ETHICS COURSE

Written by Justin Hess

# CHAPTER IV. THE DEVELOPMENT OF PERSPECTIVE-TAKING TENDENCIES

## ABSTRACT

This chapter explores the development of 19 undergraduate engineering students' perspective-taking tendencies. It revolves around a one-credit multi-disciplinary engineering ethics course offered at a Large Mid-Western University during the Spring of 2014. The primary research purposes are to explore whether students' had increases in their empathic perspective-taking tendencies as a result of participating in this course, and to discover what components of the course may have led to these developments. It follows a concurrent mixed methodological research approach, first analyzing students' changes in self-report scores to a psychometric instrument along with evaluative changes in a pre-post ethics transfer case study, and second through thematic analysis of critical incidents derived from semi-structured interviews.

Quantitative findings showed students' self-reported perspective-taking tendencies increased over the course of the semester and qualitative findings indicated there were six fundamentally distinct causes of this increase, as well as five distinct types of outcomes related to perspective-taking. The causes included (a) the sharing of diverse perspectives, (b) working through challenging case studies, (c) being tasked with self-oriented perspective-taking activities, (d) exposure to ethically stimulating cases, (e) repetitive application of the reflexive principlism approach, and (f) experiencing

cognitive dissonance. The outcomes included (a) becoming more open-minded, (b) 'holistically' taking perspectives when solving ethical dilemmas, (c) using principles to perspective-take, (d) broadening one's own worldview, and (e) becoming conscious of an engineer's social responsibility. These causes and outcomes are mapped to depict in what ways the former may have generated the latter. Taken together, the quantitative and qualitative findings are integrated to consider how perspective-taking may be promoted in engineering curricula in courses where learning objectives may be similar.

## INTRODUCTION

Engineers are agents of change (Koen, 2003) who work within accepted paradigms of their respective discipline (Kuhn, 1962) as they aspire to "create the world that never was" (Bucciarelli, 2003, p. 1). Engineers seek to make the best change with the resources available while dealing with uncertainty (Koen, 2003), all while working within economic, environmental, societal, ethical, and political constraints (National Academy of Engineering, 2005; NAE & National Research Council, 2009). Engineers must have the ability to effectively solve ill-structured problems in order to thrive in the work place (Jonassen, Strobel, & Lee, 2006) and to develop socially and environmentally acceptable engineering responses to wicked problems (Seager, Selinger, & Wiek, 2012).

Due to the nature of and risk associated with engineering work, ethics has become a primary focus for engineering educators within the United States (Herkert, 2000) and globally (Hess, 2013; Zandvoort, Van De Poel, & Brumsen, 2010). Since 2000, ABET (2014), the primary accreditation board for higher education of engineers and engineering-related fields within the United States and to a lesser extent worldwide, has required engineering students to develop “an understanding of professional and ethical responsibility” (p. 3). The National Academy of Engineering (2004) likewise suggested engineering students need to develop “high ethical standards” and a “strong sense of professionalism” in order to effectively lead in a “dynamic world” (p. 56). This is accomplished through a socialization process, potentially within the academic realm, through which students learn the values of engineering, including but not limited to safety, responsibility, and efficiency (ABET, 2014; Benya, Fletcher, Hollander, Joint Advisory Group to the Center for Engineering, & Online Ethics Center, 2013; National Society of Professional Engineers, 2013).

One core component of ethical behavior is empathy (Gibbs, 2013; Hoffman, 2000; Oxley, 2011). As social justice and morally deep concerns become central to the practice of engineering (Catalano, 2006b; Riley, 2008), a focus on embedding empathy within engineering ethics education is needed. Empathy, in particular empathic perspective-taking (Batson, Early, & Salvarani, 1997; M. H. Davis, 1996), may enable engineering students to accurately identify and understand the views of the central stakeholders involved in engineering decisions and to make decisions that are socially appropriate according to this other-centric understanding. In the context of engineering, perspective-taking is especially pertinent as it enables engineers to consider the needs and values of numerous stakeholders with whom an engineer may never directly interact. Before depicting this study’s methodology and research focus on the development of perspective-taking, scholarly literature on engineering ethics, ethics education, and empathy are explored to provide background on the role of empathy in engineering,

# LITERATURE REVIEW

This literature review begins with an overview of engineering ethics and engineering ethics education. It transitions to provide a landscape overview on conceptualizations of empathy, portraying empathy as a multi-construct phenomenon which differs by orientation between self and other, and by describing empathy functionally. It ends by emphasizing the role of empathic perspective-taking, a form of other-oriented cognitive empathy, in ethical decision-making.

## Engineering Ethics

The role of empathy within engineering ethics has been a virtually unexplored domain, despite the centrality of empathy for ethical reasoning within engineering practice (Hess et al., under review). Part of this is likely due to the term "ethics" carrying different connotations from scholar to scholar (M. Davis, 2013). A brief look at learning goals in engineering ethics courses shows instructors have a variation of ideas regarding what ethics education should achieve, ranging from "to develop moral awareness" (Boni & Berjano, 2009), "to develop skills to tackle ethical issues" (Bowden, 2010), "to enhance ethical awareness through cultivating a knowledge of ethical theories" (Chang & Wang, 2011), "to learn the world context of engineering work" (Iino, 2005), and more. M. Davis (2013) suggested ethics usually is used in one of three senses: (a) as morality, or the standards of conduct that apply to all moral agents such as virtue or character, (b) as a moral philosophy or ethical theory, or (c) standards of conduct applying to members of a group.

Probably using an understanding of ethics similar to the “standards of conduct” understanding of ethics specified by M. Davis (2013), most professional engineering societies have developed unique codes of ethics applicable to their individual profession. One interdisciplinary professional organization, the National Society of Professional Engineers (NSPE, 2015), addresses the professional concerns of licensed Professional Engineers across all engineering disciplines. NSPE has developed six fundamental canons stated as follows;

Engineers, in the fulfillment of their professional duties, shall:

1. Hold paramount the safety, health, and welfare of the public.
2. Perform services only in areas of their competence.
3. Issue public statements only in an objective and truthful manner.
4. Act for each employer or client as faithful agents or trustees.
5. Avoid deceptive acts.
6. Conduct themselves honorably, responsibly, ethically, and lawfully so as to enhance the honor, reputation, and usefulness of the profession.

**Ethics Education within Engineering**

Perhaps due to the multiple definitions of ethics, embedding ethics education within engineering is a relatively novel area of research with numerous learning goals vying for attention (Hess, 2013). Harris Jr, M. Davis, Pritchard, and Rabins (1996) suggest some of the most important learning goals of engineering ethics education include (a) “to stimulate the ethical imagination of students”, (b) “to help students recognize ethical issues”, (c) “to help students analyze key ethical concepts and principles that are relevant to the particular profession or practice", (d) "to help students deal with ethical disagreement, ambiguity, and vagueness", and (e) "to encourage students to take ethical responsibility seriously" (p. 94). Newberry (2004) condensed this list into three broad categories: (a) emotional engagement, (b) intellectual engagement, and (c) particular knowledge. Newberry describes these learning goals as students *wanting* to make ethical decisions, *knowing* how to make ethical decisions, and developing a general awareness of guidelines for ethical practice.

Rather than focus on objectives per se, the National Academy of Engineering (2009) suggested students needed to develop certain skills to reason through ethical issues, including:

1. Recognizing and defining ethical issues.
2. Identifying relevant stakeholders and socio-technical systems.
3. Collecting relevant data about the stakeholders and systems.
4. Understanding relevant stakeholder perspectives.
5. Identifying value conflicts.
6. Constructing viable alternative courses of action or solutions and identifying constraints.
7. Assessing alternatives in terms of consequences, public defensibility, institutional barriers, etc.
8. Engaging in reasoned dialogue or negotiations.
9. Revising options, plans, or actions.

Despite the numerous learning goals and pedagogical approaches to ethics education within engineering, case study has become one of the most prominent means of engaging engineering students in ethical issues (Haws, 2001; Hess, 2013). Aamodt and Plaza (1994) describe this pedagogical method as cased-based reasoning, which has the ultimate goal of enabling students to solve “a new problem by remembering a previous similar situation and by reusing information and knowledge of that situation” (p. 2). Jonassen et al. (2009) suggest exposing students to this case-based approach is valuable due to the ill-structured nature of engineering problems. When working through ill-structured problems in the workplace, engineers encounter conflicting stakeholder values. As a result, engineers must be capable of reasoning through potentially conflicting perspectives when there is no obvious right or wrong method by which to proceed forward.

Beyond the fundamental canons described above, NSPE identified many rules of practice for engineers to follow. Within the classroom simply teaching students “codes” or “rules” such as these has been one of the most popular methods of teaching ethics to engineers (Haws, 2001), where students apply the codes to particular situations or cases (Chung & Alfred, 2009; Harris Jr, 2004). Critics of the “individualistic approach” of teaching only rules suggest this focus is too narrow (Conlon & Zandvoort, 2011; M. Davis, 2006) because codes may restrict attention to micro-ethics issues, when the focus should instead be on macro-ethics, or societal issues (Bucciarelli, 2008). However, there are many proponents for applying codes or rules in situ or to a case (Abaté, 2011; Harris Jr et al., 1996). While codes may be useful at anticipating historically impactful or frequently recurring problems, they often have limited applicability when dealing with novel ethical dilemmas (Beever & Brightman, 2015; J. Flanagan & Clarke, 2007).

Although the course-specific learning objectives should drive the pedagogical strategy employed by engineering ethics educators (Li & Fu, 2012), in general, Harris Jr. et al. (1996) consider the usage of case studies as the "best way to teach engineering ethics" as students learn to "draw the line" between "acceptable and unacceptable actions" (p. 94). Case studies seem to be a viable approach of engaging students in ethics coursework (Yadav, Shaver, & Meckl, 2010), but overall there is "little empirical research on whether the use of cases is the most effective teaching method in promoting ethical understanding for engineering students" (Yadav & Barry, 2009). Case studies, if delivered effectively, may promote students to transfer knowledge outside of the course to real-world situations, especially cases in which the students become emotionally engaged (Thiel et al., 2013).

Bagdasarov et al. (2013) found that the content of a case along with associated variables are important considerations to promote student learning and transfer. One associated variable they described was "goal focus". The authors suggest that when students "are provided information about the motive behind a character's actions, the reader [student] can better understand the reasons for that character's approach to a problem" (p. 1308). According to these authors, this understanding enables students to develop clear mental models to fully understand the competing sides of an ethical dilemma within a case.

This idea regarding the importance of understanding the stakeholders' motives is closely interconnected with the theory guiding this chapter. Not only must an engineer understand a stakeholder's motives, but also they must effectively empathize with this stakeholder in order to accurately understand that stakeholders' motives, overcome potential egocentric biases, and become motivated to respond accordingly in an ethical manner. The next section includes an extensive exploration of scholarly literature on empathy. The subsequent section expands upon the theory regarding the role of empathy in ethical decision-making.

**Conceptualizing Empathy**

In this chapter, the focus is on empathic perspective-taking. Perspective-taking is an "advanced cognitive" (Hoffman, 2000) "other-oriented" (M. H. Davis, 1996) form of empathy that includes affective and self-oriented components. Table 4.1 depicts these nuances taxonomically. This categorization does not suggest that each of these empathy components are unrelated, only that they are distinct.

**Table 4.1:** *A taxonomy of distinct modes of empathy*

| | Affective/Experiential Outcomes | | Cognitive Processes |
|---|---|---|---|
| **Self-oriented** | **Emotional contagion**<br>Holding a specific internal state as a result of another or others' states | ↔ | **Projection**<br>Imagining how one would think and feel in the position of another |
| **Pluralism** | ↕ A duality between self and other orientations | | |
| **Other-oriented** | **Empathic concern/joy**<br>Feeling concerned or happy for another or others | ↔ | **Perspective-taking**<br>Imagining how another or others think or feel |

The specific "type" of empathy focused on tends to vary from field to field, and even within a given field (Batson, 2009; Gerdes, Segal, & Lietz, 2010). Batson (2009) suggests there exist 8 common conceptualizations or attributes of empathy today, and that these distinct conceptualizations are the result of two distinct questions researchers have tried to answer: (a) how do we know another's thoughts and feelings? and (b) what leads one to respond with sensitivity and care to the suffering of another? Table 4.1 is a simplified version of Batson's eight empathy types, perhaps at the exclusion of two common usages of empathy: (a) mimicry (posture-matching) and (b) empathic distress. In Hoffman's (2000) framework, empathic distress is the tendency for one to become tense or distressed due to an "other-oriented" understanding. For Hoffman, empathic distress is key for driving action. Literature on whether this reactive response is inherently altruistic or egoistic is emerging (e.g. see Stich, Doris, & Roedder, 2012 working out of the novel field of moral psychology).

Lawrence et al. (2006) distinguishes between "cognitive" and "affective" empathy, where the cognitive aspect involves "understanding and predicting someone else's mental state" and the affective aspect involves "experiencing an emotion as the result of someone else's mental state" (p. 1173). M. H. Davis (1983) suggests empathy is best conceptualized as a multi-dimensional construct than as either solely cognitive or affective. Like Batson, Mark H. Davis frames empathy as consisting of multiple sub-constructs, including:

1. Perspective-taking, or the tendency "to spontaneously adopt the psychological point of view of others" (p. 113)

2. Fantasy, or the tendency "to transpose" oneself "imaginatively into the feelings and actions of fictitious characters in books, movies, and plays" (p. 114)
3. Empathic concern, or the tendency to have other-oriented "feelings of sympathy and concern for unfortunate others" (p. 114)
4. Personal distress, or the tendency to have self-oriented "feelings of personal anxiety and unease in tense interpersonal settings" (p. 114)

In M. H. Davis's conceptualization of these empathy sub-constructs, an individual may be more proficient at one empathy type than another may be. For example, perspective-taking does not necessarily require one to have other-oriented feelings of empathic-concern. These sub-constructs differ in terms of orientation, meaning they may be self-oriented, other-oriented, or a combination of both. The following sections provide a rich exploration of these nuances.

**Empathy's cognitive processes**

The cognitive component of empathy considers one's ability to comprehend another's perspective with some level of accuracy through what Ickes (2009) called *empathic inference*, where "empathically accurate perceivers are those who are good at 'reading' other people's thoughts and feelings" (p. 57). If one tries to look solely at empathy's cognitive component, empathy most closely aligns with what social psychologists and neuroscientists call theory of mind (Dziobek et al., 2008). Theory of mind suggests that through understanding another's beliefs and desires (not to be confused with one's own beliefs or desires), one can explain the other's behavior

(Iacoboni & Dapretto, 2006). Premack and Woodruff (1978) first used this term in an experiment when striving to understand if chimpanzees have this mental capacity. Since then, extensive research has been conducted regarding the nature of this theory, largely with adolescents (Doherty, 2012) and individuals with psychiatric disorders (Baron-Cohen, 1997; Poletti, Enrici, & Adenzato, 2012).

Two classes of theory of mind dominate the literature. The first class is set down by *theory theorists* who "suggest that we use our lay theories about the mind to infer the internal states of others" (Batson, 2009, p. 3). For example, Brüne and Brüne-Cohrs (2006) adopt a modularity account for theory of mind. According to these authors, at certain ages children begin use of innate abilities called modules. Deficits in theory of mind are a result of the dysfunction of these modules. Around 4 years children "turn on" their ability to infer other's beliefs for the first time (Doherty, 2012). At the other end of the theorist spectrum, theory of mind has been explained as a constructive phenomenon, where through perception and action children conceptually develop their mental representations of others (Doherty, 2012).

A second camp of theorists of mind suggest individuals come to understand others through simulation. Simulation theory argues that the internalization of another's mental states involves imagining one's self in another person's position, applying one's own decision-making abilities, and then externalizing one's self-conclusion onto the other person (Doherty, 2012). Stueber (2006) explains that simulation proceeds in three phases: (a) the "matching phase" where one adopts "a different conative relation to the world in order to recreate the other's perspective of the world", (b) the "simulation phase" where after internalizing this other perspective one starts "thinking about the world from that perspective", and (c) the "attribution phase" where one ceases the simulation phase but builds upon the knowledge gained therein to interpret the cause of the other's action. Gallese and Goldman (1998) provide a depiction of the simulation theory process (see Figure 4.1) which they explain as follows,

> After observing the target agent (**T**) perform action **m**, the attributor uses simulation to test whether goal **g** would have fitted with the choice of **m**. Goal **g** is re-created and fed into his [sic.] decision-making system, which does output **m**.

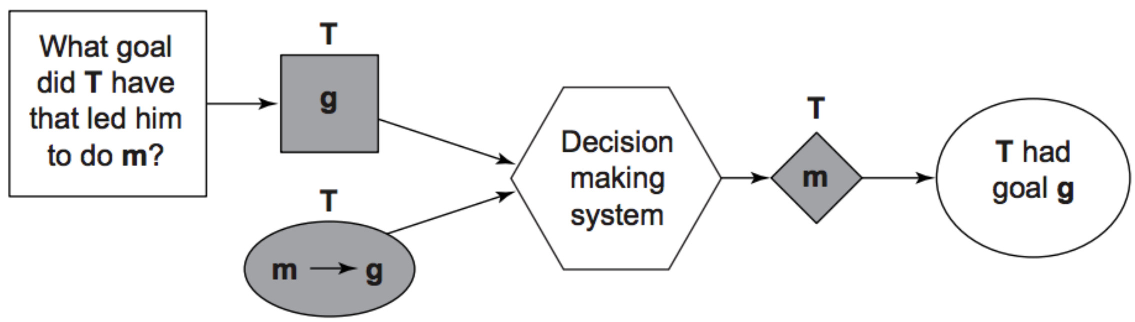


**Figure 4.1**: *Simulation theory of mind process – the attributor deduces the goal (g) of the agent (T) through observation of their behavior (m, taken from Gallese & Goldman, 1998, p. 498, License Agreement for reuse provided by Elsevier).*

This discourse makes a few distinctions between *empathy* and *theory of mind* apparent. First, theory of mind generally focuses on perspective-taking only towards other rational agents. To make sense of and adopt another's frame of mind, there must be some understanding that there is another mind to whom we have access. Second, theory of mind strives to accurately understand why separate agents think or do what they do. Once one adopts the stance that other minds do exist, there becomes a secondary issue of interpreting the states of others' minds and translating those states into accurate interpretations, which in turn would lead to relevant and appropriate actions. Third, theory of mind does not emphasize an emotive component, but as will be explained in the next section, understanding how another feels and matching that state may be essential for accurate empathic perspective-taking.

**Empathy's affective processes**

While theory of mind strives to understand how another would *think*, empathy in its truest form also considers how another would *feel*. In contrast to theory of mind, empathy (if accurate) is dependent upon affective considerations which are less about higher-order cognitive processes and more related to automated states of being (e.g. emotional contagion) that may in turn drive a behavioral response. Through affect, the implausibility of empathizing with non-rational beings becomes a non-problem (as is the case with theory of mind). In other words, one may theoretically be able to empathize with non-rational animals, plants, artifacts, and the "planet" in a very general sense, even if that "other" does not clearly have a rational mind.

Empathy's affective dimension may include empathic concern and personal distress (M. H. Davis, 1996). Here, empathic concern seems more closely related to "care" as depicted in Chapters 2 and 3, whereas personal distress is more closely related to emotional contagion, where one's internal state matches that of another (Decety & Jackson, 2004; Hatfield, Rapson, & Le, 2009; Preston & de Waal, 2002). When one's state of being aligns with another's, then that individual may become motivated to act on the other's behalf. Yet, empathic distress has a limit, where too much distress may cause one to turn their focus inward, thereby resorting to egocentric as opposed to altruistic behavior (Hoffman, 2000).

According to Hoffman (2000), the higher-order cognitive modes of empathy build upon these automatic and affective modes. Oxley (2011) likewise suggests that the affective dimension of empathy is essential for true empathy, as Oxley stresses that empathy requires congruence of emotions between individuals if empathy is to accurately perform its epistemic functions. As an example, consider a sadist who maintains a positive attitude even when cognitively understanding the distress of another. The sadist would literally fail to internalize the distressed individual's emotions, and therefore would be unable to fully grasp the other's perspective as there would be an affective disconnect between the sadist and the distressed.

Accurately adopting another's viewpoint is contingent upon other conditions, including an automatic state-matching between self and other, and even a sufficient amount of concern towards the other to have the motivation to take their viewpoint in the first place (M. H. Davis, 1996; de Waal, 2009). In other words, for accurate empathic perspective-taking, one may first need to meet some threshold of alignment in emotive states with another, and second they must value the other. This alignment may simply require emotional congruence, meaning one could hold a negative affective state as a result of another's affective state, even if those states were not exactly the same (e.g. anger as a result of another's sadness) (Hatfield et al., 2009).

**Self-, other-, and plural-oriented empathizing**

In order to cognitively empathize one must do one of two things: (a) imagine themselves in or align themselves with another's state of being or (b) imagine the other or feel for the other in their own state of being. The former is called self-oriented or "imagine-self" empathy (Stotland, 1969) and the latter other-oriented or "other-focused" empathy (Oxley 2011 p. 23). Yet, empathy is generally "pluralistic", meaning that individuals tend to reason back and forth between one's own thoughts and feelings with those of others (Batson et al., 1997; Hoffman, 2000). As de Waal (2009) explains, "The sight of another person's state awakens within us hidden memories of similar states that we've experienced" (p. 78). Simulation theory in essence describes pluralistic cognitive reasoning, where self-oriented empathy acts as the means for understanding another's perspective. Here the theorist (a) adopts the other's perspective, (b) reasons from that perspective, and (c) deduces an understanding of another while testing if it seems to fit the other based off the individual's self-oriented understanding.

Findings from neuroscience, specifically the discovery of mirror neurons, suggest when we watch an action performed by another, we literally internalize the action as if we were performing it ourselves (Iacoboni, 2009). Whenever one strives to understand someone else's thoughts or feelings, this individual inevitably begins to think and feel as if they were the other. Oxley (2011) suggests this is a strength of empathy, writing, "Knowledge gained with empathy is framed in reference to oneself, and this is why it is important for moral deliberation: empathy can transform one's view of others, one's view of what is valuable, and one's view of what matters, both to others and to oneself" (p. 12).

Therefore, empathizing with others through adoption of their perspectives may change one's internal perspective, and ultimately lead one to a more interpersonal approach to solving a problem or making a decision.

**A functional model of empathy**

What has not been described in detail up to this point is that empathy may also be depicted as the caring relationship between self and other (Wiseman, 2007) or as a behavioral response based off one's caring for or understanding of another (Levenson & Ruef, 1992). Hoffman (2000) depicts empathy in this manner, suggesting empathy is the "spark of human concern for others" and "the glue that makes social life possible" (p. 3). In other words, for Hoffman, empathy entails not only understanding another's needs but also responding with a socially appropriate solution. Adding the behavioral connotation, Hatfield et al. (2009) suggests true empathy includes three distinct skills: "the ability to share the other person's feelings, the cognitive ability to intuit what another person is feeling, and a 'socially beneficial' intention to respond compassionately" (p. 19).

Building on his previous work in social psychology, M. H. Davis (1996) developed a functional model of empathy, which consisted of (a) antecedents or inputs that lead to (b) empathic processes (which he defined as non-cognitive, simple cognitive, and advanced cognitive), which generate (c) interpersonal and (d) intrapersonal outcomes. M. H. Davis' model supports the view that empathy is not an exclusively rational ability but instead grounded in prior knowledge, instinct, and intuition.

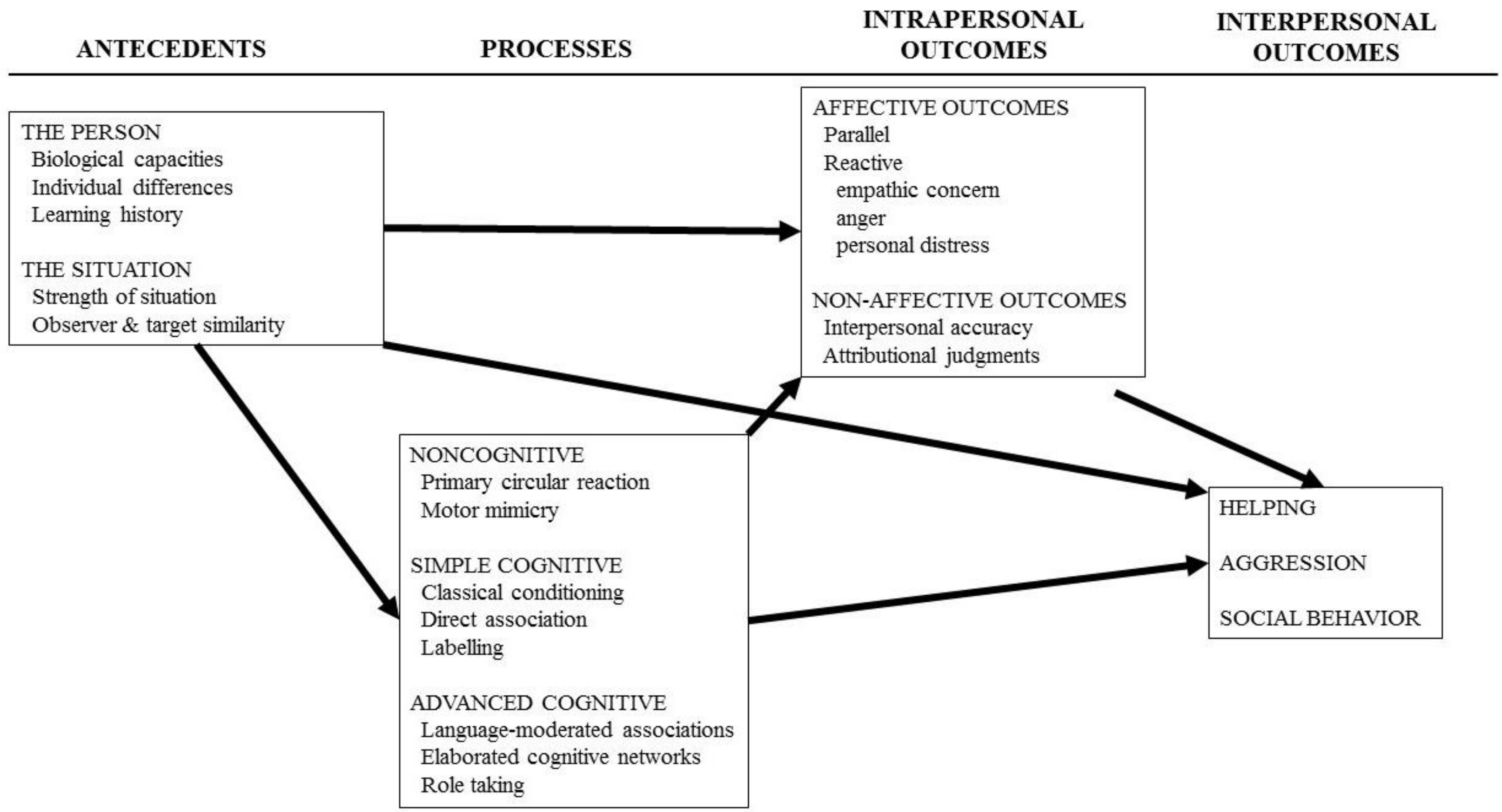


**Figure 4.2**: *A functional model of empathy (adapted from M. H. Davis, 1996, p. 13)*

These support reasoning skills at the advanced cognitive level, which may lead to interpersonal helping behavior. M. H. Davis's (1996) functional model (see Figure 4.2) highlights the complexity and nuances of empathy, as evident throughout this literature review.

As described earlier, perspective-taking is an advanced cognitive form of empathy and builds upon several antecedents, including one's capacity to take another's perspective, the salience of the other's situation to the perceiver, and the recognized similarity between the observer and the observed. Therefore, empathic perspective-taking is in part based upon experience (e.g. the more experiences one has with others, the more likely they are to comprehend similarities with others) and partially based on one's open-mindedness (e.g. a greater capacity for seeing similarities between one's self and diverse others). Taken together, empathic perspective-taking may lead to various outcomes, be they in the form of understanding another (emotively and cognitively) or actually helping another.

**Empathy and Ethical Decision-Making**

In general, engineers do not interact with each and every stakeholder impacted by their engineering decisions, so they must have some ability (and tendency) to accurately consider the perspectives of stakeholders with whom they have not had face-to-face contact. For Hoffman (2000), this ability stems from the most advanced form of empathy, what he called role-taking and we have thus far referred to as perspective-taking. Perspective-taking enables one to consider the perspectives of individuals not currently present. In the context of engineering, this seems especially pertinent, as engineers make decisions that impact numerous stakeholders.

Gibbs (2013) argues that ethical decisions must be justified through an act of social perspective-taking, where actions can be considered justifiable insofar as they are considered reversible. Oxley (2011) likewise considers empathy to be key to ethical decision-making, as she suggests empathy invokes a salience effect, leading to moral deliberation that is inclusive of diverse perspectives. While Oxley focuses on empathy's epistemic function that results from its cognitive processes, she emphasizes that empathy is built upon core, non-cognitive, affective components. This is similar to Hoffman's (2000) model, where empathic perspective-taking is the fifth and most 'advanced cognitive' form of empathy. For Hoffman (2000), any type of empathy may lead to a behavioral response, but he notes that the nearer one is the more likely one is to empathize with that other (Hoffman referred to this as here-and-now bias).

Building from this literature, Hess, Beever, Strobel, and Brightman (under review) extensively developed a framework describing the relationship between the advanced cognitive form of empathy, empathic perspective-taking, and ethical decision-making within engineering. These authors depict how empathic perspective-taking may play a core role in a series of real-world engineering case studies, such as morally deep considerations in light of technological development (Catalano, 2006a), historical cases such as the Challenger explosion (Harris Jr, Pritchard, Rabins, James, & Englehardt, 2014; Niewoehner & Steidle, 2009), social justice concerns (Riley, 2008), and 'everyday engineering' design situations (Bovy & Vinck, 2003; Vinck, 2003). By using these case examples, Hess et al. (under review) show how empathic perspective-taking plays a key role in deducing acceptable levels of risk within engineering design, reaching socially justifiable engineering decisions, and incorporating sustainability considerations into ethical decision-making processes. The authors conclude:

> *…we posit that empathic engineers will have a greater tendency to (a) consider the full range of stake-holders potentially impacted by an engineering decision, (b) value these stakeholders' perspectives for those stakeholders' own sakes, (c) reason back and forth between stakeholders' values and their own, (d) come to a socially justifiable decision through mitigation of potential conflicts of interest, (e) justify their decisions by attempting to balance a multiplicity of stakeholders' needs, and (f) consciously establish a means to gather on-going feedback from these stakeholders in order to evaluate the accuracy of their perspective-taking and to re-evaluate their decision reflectively*.

Hess et al. (under review) do not empirically explore how empathic perspective-taking tendencies may be induced as part of the engineering curriculum. Engineering faculty indicated that empathy may be incorporated 'indirectly' into curricula, such as within an existing course as opposed to a course of its own (Strobel et al., 2013). Within engineering ethics in particular, engineering students are already commonly required to discover and describe diverse perspectives (Coso, 2014; Hess, 2013; Loui, 2005; May & Luth, 2013) but whether students are expected to empathically engage in those stakeholders' perspectives is seldom made explicit, and was never the stated learning goal in the sources identified by Hess (2013).

What this study provides is the first exploration of whether students develop increased perspective-taking tendencies as a result of participating in a multi-disciplinary engineering ethics course. As such, the guiding research foci include, “Does participation in an engineering ethics course increase students’ empathic perspective-taking tendencies?” and “Which components of an ethics course may be most critical for inducing perspective-taking changes?” The section on methodology expands these research questions, but first, the next sections presents the theoretical framework.

## THEORETICAL FRAMEWORK

This section provides an overview of the epistemological assumptions of the research methods used herein. Epistemology “describes the assumptions we are making about the nature of knowledge and what counts as evidence” (Baillie & Douglas, 2014, p. 2). The underlying philosophical assumptions regarding what counts as knowledge may be referred to as paradigms or worldviews (Creswell & Plano Clark, 2011; Kuhn, 1962; Mackenzie & Knipe, 2006). In Kuhn’s (1962) seminal work on the structure of scientific revolutions, he suggests there does not exist any facts or fundamental truths without a core or underlying paradigm. Regardless of whether an author makes their guiding research paradigms explicit, paradigms permeate all aspects of any research endeavor.

The traditions of qualitative and quantitative research hold core paradigms that are generally distinct, but not necessarily incommensurable (Crotty, 1998; Greene & Caracelli, 1997). A mixed methodological framework may be oriented to use distinctions between paradigms advantageously, where the strengths and weaknesses of one paradigm are mitigated or bolstered by those of the other (Creswell & Plano Clark, 2011;

Flyvbjerg, 2001). Paradigms differ “in the nature of reality (ontology), how we gain knowledge of what we know (epistemology), the role values play in research (axiology), the process of research (methodology), and the language of research (rhetoric)” (Creswell & Plano Clark, 2011, p. 41). The following sections first presents a post-positivistic paradigm, followed by an interpretivist paradigm, and lastly, a consideration of how these distinct paradigms work together dialectically in this research study.

**Post-Positivistic Framing**

The implementation of survey and experimental research, common within quantitative research traditions and throughout the engineering education research community (Borrego, Douglas, & Amelink, 2009), entails a positivistic (Walsham, 1995) or post-positivistic (Creswell & Plano Clark, 2011; Mackenzie & Knipe, 2006) epistemology where the data can be reduced to selected variables and tested against carefully articulated theories. The positivistic paradigm holds that “[o]bjective reality exists beyond the human mind” (Weber, 2004, p. iv) and “there is one truth about the world that we can discover” (Baillie & Douglas, 2014, p. 2). In this ‘objective’ form of research, the values of the researcher are not seen as influential to the research results (Walsham, 1995). Positivism and post-positivism differ primarily in terms of what may count as truth and how rigid that truth becomes once ascertained. The post-positivistic paradigm, in contrast to positivism, suggests unobservable reality “has existence and the capability of explaining the functioning of observable phenomena” (Clark, 1998, p. 1245). In addition, post-positivism holds that any “truth” is contingent upon a guiding theoretical framework, and that this framework itself is susceptible to change (Kuhn, 1962; Mackenzie & Knipe, 2006). In the context of post-positivistic research, by implementing a psychometric instrument or rubric to quantify empathic tendencies or responses of an individual, we assume that an individual's empathic tendencies are knowable and quantifiable, and that this quantized data is comparable across individuals.

**Social Constructivist Framing**

Qualitative research paradigms vary widely according to numerous paradigms, which range from post-positivism, interpretivist, participatory, emancipatory, pragmatism, and many others (Borrego et al., 2009; Creswell, 2007). Walther, Sochacka, and Kellam (2013) define interpretive research as "social inquiry that derives knowledge claims from the interpretation of lived experiences of individuals or groups" where "social reality is locally and specifically constructed" (p. 628). Interpretive researchers recognize the inherent subjectivity of their results, as a researcher's prior experiences play a role in their interpretation throughout the research process (Walsham, 1995). In terms of creating meaning from the data, the researcher and the participants are seen as partners (Borrego et al., 2009) as the interpretivist paradigm holds that "our knowledge of reality is a social construction by human actors" (Walsham, 1995, p. 376) and "[k]nowledge of the world is intentionally constituted through a person's lived experience" (Weber, 2004, p. iv).

Social construct*ivism* is one type of interpretivist paradigm which holds that "human beings can interpret their surroundings" where their personal stories contain inseparable facts and truths (Baillie & Douglas, 2014, p. 2). Social construct*ionism* is a distinct paradigm where the focus is on a shared social understanding. Baillie and Douglas (2014) further explain the distinction as follows:

> …social constructionism refers to an understanding about the world as jointly 'constructed' with other human beings – in other words, people with this epistemology believe that reality is socially constructed, not absolute as do positivists. Social constructivism, on the other hand, usually refers to the ways in which an individual constructs knowledge about the world in his or her social context. (p. 2)

This research study is of the latter sort, where the goal is to focus in on how individuals interpreted their experience with the phenomenon of interest. Specifically, the focus is not on how individuals think perspective-taking may change for anyone, but rather, from their experience in an ethics course, what incidents or events sparked some form of change for themselves. Nonetheless, this interpretivist paradigm recognizes that learning is inherently social and "cultural activities and tools (ranging from symbol systems to artifacts to language) are regarded as integral to conceptual development" (Palincsar, 2005, p. 286f). While the students verbalize their own experiences, these students' experiences are embedded within a social context.

Interpretive research traditions hold that data cannot be completely neutral or unbiased as the researcher brings their prior conceptions to the study, even if attempting to bracket these prior conceptions (Walther, Sochacka, & Kellam, 2013). Furthermore, researchers actively interact with participants in their study, potentially impacting the nature of the participants' responses. Therefore, interpretive researchers recognize they interpret the findings through their own lens which is not singular, final, or necessarily the correct view (Kirk & Miller, 1986). Furthermore, “Researchers recognize that their own background shapes their interpretation, and they ‘position themselves’ in the research to acknowledge how their interpretation flows from their own personal, cultural, and historical experiences” (Creswell, 2007, p. 21).

**Embracing Multiple Paradigms Dialectically**

Mertens and Hesse-Biber (2013) suggest, “Some of the most important problems and prospects of deploying mixed methods evaluation designs across the evaluation process involve issues of mixing paradigmatic approaches” (p. 7). According to Greene and Caracelli (1997), the perspectives regarding the compatibility of mixing paradigms falls into three camps. First, the “purist” perspective regards paradigms stemming from distinct traditions to be incompatible. Second, the “pragmatist” perspective suggests these “philosophical assumptions are logically independent and therefore can be mixed and matched”. Lastly, the “dialectical” perspective recognizes different paradigms do exist and believes their differences must be honored. Nonetheless, according to the purist perspective, distinct paradigms may be used together “both within and across studies toward a dialectical discovery of enhanced understandings, of new and revisioned perspectives and meanings” (Greene & Caracelli, 1997, p. 8).

According to Greene and Caracelli (1997), the dialectical perspective tends to embrace “using methods shaped by both interpretivist and postpositivist paradigms in an integrative manner to generate more comprehensive, insightful, and logical results than either paradigm could obtain alone” (p. 10). In an earlier study, Greene, Caracelli, and

Graham (1989) suggested "a short quantitative method could be paired with a longer qualitative method" (p. 264). Creswell & Plano Clark's (2011) capture this idea, writing:

> *…if a study begins with a survey, the researcher is implicitly using a postpositivist worldview to inform the study beginning with specific variables, empirical measures, and often framed within an a priori theory that is being tested in the survey project. Then, if the researcher moves to qualitative focus groups in the second phase to follow up on and explain the survey results, it seems like the worldview shifts to more of a constructivist perspective. In the focus group, the attempt is to elicit multiple meanings from the participants, to build a deeper understanding than the survey would yield, and to possibly generate a theory or pattern of responses that explain the survey results. (p. 45f)*

What the dialectical perspective suggests then is the researcher may adopt different guiding paradigms within a single study, moving between them sequentially or concurrently. The dialectical perspective guides this study, as the methods described in the following sections move from a quantitative post-positivistic epistemological orientation to a qualitative social constructivist lens. With this epistemological orientation in mind, this chapter turns to the methodology which includes guiding research purpose and questions, followed by an overview of this research study alongside an overview of the ethics course used as the 'intervention' in this study.

## METHODOLOGY

The research focus in this study is on how engineering curricula can develop students' empathic perspective-taking tendencies, specifically, which components of an engineering ethics course most critically contribute to the development of engineering students' empathic perspective-taking tendencies. This section on methodology begins with a description of the guiding research purposes and questions, followed by an overview of the mixed methods research framework employed. This section concludes with an overview of the ethics course around which this study revolved, including the content students worked through and the accompanying pedagogical framework. A more detailed description of the quantitative and qualitative methods follows in their respective sections.

**Research Purpose and Questions**

The first purpose of this work is to determine whether a multi-disciplinary engineering ethics course facilitates gains in the participating engineering students' empathic perspective-taking tendencies using a post-positivistic paradigm. As such, the initial research question is:

> **RQ1**: Does participation in an engineering ethics course designed to introduce students to the reflexive principlism ethical reasoning approach through a staged pedagogical framework and multi-disciplinary case studies develop students' empathic perspective-taking tendencies as measured by the Interpersonal Reactivity Index and an Ethics Transfer Case?

A follow-up research purpose is to qualitatively explore the nature of any changes that were not detectable by the quantitative results alone, along with a deeper exploration of the potential causes of these changes. Here, the goal is to explore which experiences students consider to be the most positive or critical factors influencing changes in their empathic perspective-taking tendencies, if any. As such, the second guiding research question is:

**RQ2**: From the perspective of course participants, which components of this engineering ethics course critically influenced the development of their empathic perspective-taking tendencies, if any, and what was the nature of this development?

Lastly, a final research purpose is to integrate the qualitative and quantitative findings. The goal for this mixed portion of the study is to consider in what ways the qualitative findings support the quantitative, as well to explore any contradictions that may arise between the two phases. As such, the third and final research question for this study is:

**RQ3**: What insights emerge from integrating the qualitative results regarding students' critical experiences with the quantitative results from the Interpersonal Reactivity Index and Ethics Transfer Case?

**Convergent Parallel Research Design**

This study includes three phases corresponding to each of the guiding research questions. Taken together, the study follows a triangulation mixed methodology (Creswell et al., 2003; Borrego et al., 2009) which entails a convergent parallel research design where equal weight is given to qualitative and quantitative data. As Creswell and Plano Clark (2011) explain, "The convergent design involves collecting and analyzing two independent strands of data in a single phase; merging the results of the two strands; and then looking for convergence, divergence, contradictions, or relationships between the two databases" (p. 116). According to Borrego et al. (2009), the "mixing" occurs either when the results are interpreted or throughout the analysis.

Figure 4.3 provides a process map of this study's research design.

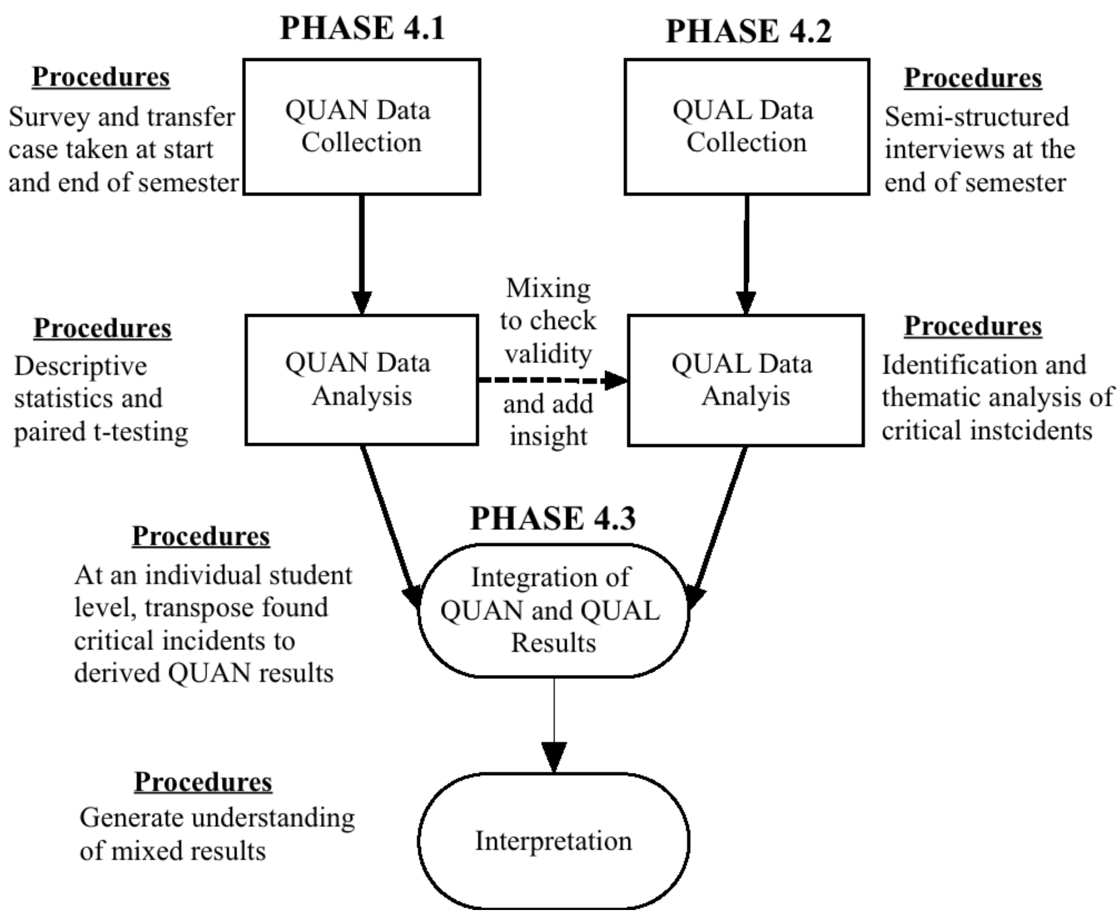


**Figure 4.3**: *Convergent parallel mixed methods research design*

The philosophical orientation of this approach shifts when working with the quantitative data as opposed to the qualitative. Phase 4.1 follows a post-positivistic paradigm, analyzing quantitative pre-post data measuring students' empathic perspective-taking tendencies gathered using a psychometric instrument called the Interpersonal Reactivity Index (IRI, M. H. Davis, 1980, 1983) and by "quantizing" written (Borrego et al., 2009) responses to an Ethics Transfer Case using a validated rubric. While the IRI is a 5-point Likert self-report measure, the Ethics Transfer Case involves scoring of written responses to a case study prompt. Initial development and validation of the Ethics Transfer Case methodology is described by Hess et al. (2014).

Phase 4.2 transitions to a social constructivist paradigm, collecting and analyzing semi-structured end-of-semester interviews. Students participated in interviews within a week of the students' completing the IRI and Ethics Transfer Case, and as such, we did not analyze changes between pre- and post- course responses prior to conducting the interviews. Throughout the analysis of interviews, the unit of analysis is the critical incidents extracted from the interviews. We map these incidents into distinct themes according to the second research question.

Phase 4.3 integrates findings from Phases 4.1 and 4.2 to expand upon any surprising insights gathered from the first two phases. The upcoming sections further explore the methods employed within Phases 4.1 and 4.2, but first, the following sections describe background on the course content and pedagogical framework.

**Course Overview**

This research study revolves around a multi-disciplinary engineering ethics course offered through the school of Biomedical Engineering at Purdue University during the Spring of 2014. 19 students of various backgrounds participated in the course. The course title was "Solving Ethical Problems in Engineering: A Course in Multidisciplinary Engineering Ethics". The Spring 2014 course syllabus is included in Appendix C. This study was approved for exemption through Human Protection Program Institution Review Boards at Purdue.

The course was developed as part of a National Science Foundation Ethics Education in Science and Engineering (EESE) research grant (Brightman & Kisselburgh, 2012) in which case study modules were developed and delivered to students through a six-stage pedagogical framework (Kisselburgh et al., 2014). The primary goals of the EESE grant is to develop cases (some novel, some already being used within engineering curricula) within the proposed pedagogical framework, determine what components of the course engage students to the greatest extent, which components of the course students find most satisfactory, evaluate the efficacy of reflexive principlism as a guiding moral reasoning approach within engineering (see Beauchamp, 2007; Beauchamp & Childress, 2013; Beever & Brightman, 2015), and to determine the most appropriate means of evaluating developments in students' ethical-reasoning abilities. The specific research goals of this chapter are distinct from but not incongruent with the larger goals of the EESE research grant.

**Course content**

To begin the course, students worked through a "meta-module" which introduced them to reflexive principlism as an ethical-reasoning approach. Throughout the remainder of the course, students worked through a series of four multi-disciplinary case studies that ranged from biomedical ethics to environmental and civil engineering. While most of the work through the cases required individual tasks, towards the end of each of these case studies students had to apply the reflexive principlism approach to come to an ethical decision within a team setting through submission of a group case report. During the Spring 2014 course offering, students were divided into four teams consisting of four or five individuals each.

A professor with expertise in the scholarly domain of each case led the respective case. The cases were presented to students in the following sequence and led by the associated faculty or practitioner (their positions are described according to the professional position at the time of delivery of the case):

1. Development and distribution of tissue engineered heart valves (see Merryman, 2008), led by Dr. Michael Hiles, Chief Scientific Officer for Cook Biotech
2. Kansas City Skywalk Collapse led by Dr. Matthew Krane, Associate Professor of Materials Engineering at Purdue University
3. Development and distribution of medical devices that measure “Osteopenia” led by Dr. Andrew Brightman, Assistant Head of Biomedical Engineering at Purdue University
4. The Deepwater Horizon oil spill led by Dr. Jonathan Beever, Postdoctoral Scholar at The Rocks Ethics Institute at Pennsylvania State University

**Pedagogical framework**

In this section, I describe the pedagogical framework guiding the course. The instructors presented multiple cases to students participating in a graduate level engineering ethics class. Each of the course cases exposed students to unique ethical situations and, therein, a wide breadth of stakeholder perspectives were applicable. Perspective-taking activities were a core part of the process, which is unique from most pedagogical methods described in engineering ethics literature. Table 4.2 presents the stage model of the pedagogical framework used throughout the course. Students worked through each case study n this six-stage sequence, with students moving somewhat linearly from one stage to the next over a three-week period which involved two interactive lectures. Likewise, the instructors designed and implemented case in a similar manner for each.

At the beginning of each case study students established foundational knowledge by watching videos made by the leading professorate on the case, skimming selected readings, working through one or multiple "quick checks", or posting a written response online. During Stage 2, students worked through a perspective-taking activity where they identified stakeholders affected by the case, reasoned from the perspective of a stakeholder involved in the case, or considered how to balance competing stakeholder claims (see Appendix D for the full list of these activities corresponding to each case study). In Stage 3 students either participated in an in-class interactive lecture or watched that week's corresponding recorded video lecture. In Stage 4 students reviewed an ethicist's take on the relevant moral issues via videos or assigned readings. In Stage 5 students participated or watched a second in-class session, and then worked amongst their team to respond to a case-specific ethical question by developing a group case report. Lastly, during Stage 6 and as a final case activity, students answered two reflection questions, prioritizing the ethical principles as they applied to the case and explaining their prioritization.

With the exception of Stage 6, students posted their written responses to a discussion thread within the Pearson OpenClass learning environment. Depending on the activity, students may have been required to respond to their group members' posts.

**Table 4.2**: *Ethics course content delivery model (adapted from Kisselburgh et al., 2013)*

| ***Stage #:* Learning Type** | ***Stage 1:* Establishing Knowledge** | ***Stage 2*: Perspective Taking** | ***Stage 3*: Compare & Contrast** | ***Stage 4*: Inducing Conflict** | ***Stage 5*: Decision-making and Justification** | ***Stage 6*: Reflection and Reflexivity** |
|---|---|---|---|---|---|---|
| **Type of Content:** | Scenario, facts, and expert info about emerging technology | Stakeholder perspectives | Comparing perspectives | Common ethical principles | Debate with justification; Opinion by technical ethicist | Meta-reflection on ethics and process |
| **Form of Content:** | Multimedia - video and text (multiple perspectives) | Responsive writing / Journaling | Multimedia responses in text, voice, video | Expert ethicist's presentation (video, slides, text) | Live web-video conferences & Recorded statement | Multimedia responses in text, voice, video |
| **Learning Activity:** | Narrative | Reflection | Moderated Discussion | Listening / Reading | Facilitated Debate | Meta-reflection |

PHASE 4.1: ASSESSING CHANGES IN EMPATHIC PERSPECTIVE-TAKING

The first phase of this portion of the study addressed the initial research question: *Does participation in an engineering ethics course designed to introduce students to the reflexive principlism ethical reasoning approach through a staged pedagogical framework and multi-disciplinary case studies develop students' empathic perspective-taking tendencies as measured by the Interpersonal Reactivity Index and an Ethics Transfer Case?*

I address this research question quantitatively through analysis of 19 students' pre- and post- course responses to a psychometric instrument and assessment of students' written responses to a case study. Due to the low sample size, statistical power is likely to be low, meaning there will be a high risk of committing a Type II error (failing to detect a significant increase in perspective-taking when there actually was one). The following sections explain the data collection and analysis procedures in greater detail, followed by an overview of the quantitative results.

**Quantitative Data Collection**

This section describes two quantitative measures: (a) a self-report psychometric instrument and (b) an Ethics Transfer Case methodology. The psychometric instrument is the Interpersonal Reactivity Index (IRI). This instrument was developed and validated by Mark H. Davis (1980; 1983) in the field of social psychology and has been used extensively in many domains, including engineering (Rasoal, Danielsson, & Jungert, 2012). Further, it has been validated in many geographic regions and language contexts, including Dutch (De Corte et al., 2007) and Chinese (X. Huang, Li, Sun, Chen, & M. H. Davis, 2012; Siu & Shek, 2005).

The IRI measures empathy along four distinct dimensions or subscales which include: (a) fantasy, (b) perspective-taking, (c) empathic concern, and (d) personal distress. I gathered permission to use this instrument from Dr. M. H. Davis via e-mail. In this study, students answered self-report questions along a 5-point Likert-scale ranging from “1, Does not describe me well” to “5, Describes me very well”. For purposes of this study, as explained in the theoretical framing, the primary factor of interest from the IRI is perspective-taking, defined by M. H. Davis (1983) as “the tendency to spontaneously adopt the psychological point of view of others” (p. 114). Table 4.3 shows the items or questions that correspond to perspective-taking, whereas Appendix E contains a complete list of all questions on the IRI.

**Table 4.3:** *Perspective-Taking items in the Interpersonal Reactivity Index*

| Item # | Survey Item |
|---|---|
| Q3 | I sometimes find it difficult to see things from another's point of view. (reverse coded for analysis) |
| Q8 | I try to look at everybody's side of a disagreement before I make a decision. |
| Q11 | I sometimes try to understand my friends better by imagining how things look from their perspective. |
| Q15 | If I'm sure I'm right about something, I don't waste much time listening to other people's arguments. (reverse coded for analysis) |
| Q21 | I believe that there are two sides to every question and try to look at them both. |
| Q25 | When I'm upset at someone, I usually try to "put myself in his shoes" for a while. |
| Q28 | Before criticizing somebody, I try to imagine how I would feel if I were in their place. |

The Ethics Transfer Case is a more time-intensive activity that students were tasked to complete at the beginning and again at the end of the course. The case study prompt had students consider what course of action was most ethical for an engineer to recommend to his or her company in light of proposed, more stringent EPA regulations regarding wood stove emissions in the State of Maine. The 'engineer' worked for a top wood stove manufacturer in Maine and had the added role of serving as an EPA consultant. Taking on this role, students created a visualization of their thought process for reasoning through the most ethical course of action for the company to take. Along with their visualization, students submitted a series of written responses explaining the steps they took and what further information they would need. The full activity prompt is included in Appendix F.

Students completed the IRI and the Ethics Transfer Case prior to completing any other coursework, and they submitted their post-course responses only after completing all other course activities (except interviews). We used Purdue Qualtrics to collect responses.

**Participant overview**

The course instructors incentivized participants to participate in each activity by gaining a course percentage point for completing the survey each time. The IRI was situated within a larger survey that measured students' satisfaction and engagement with ethics education. Taken together, the pre- and post-course submissions for these assessment measures were worth 16 percentage points. In the pre-course survey, we collected demographic information at the end of the survey. Overall, the survey took the majority of students between 15-20 minutes to complete. The time to complete the Ethics Transfer Case could not be reliably determined, although we recommended to participants that they complete the task within one hour.

19 students participated in the course during the Spring of 2014. All 19 participants completed each pre- and post- survey, including each question on these surveys. 11 of the participants participated in a weekly lecture throughout the semester, whereas the remaining 8 participated by distance asynchronously, watching the weekly recorded lectures rather than being physically present in-class. Each of these distance

students were part-time students, pursuing Master's Degrees, enrolled through Purdue's Online MSE program. These students held full-time positions outside of academia throughout the duration of the course (mostly occupations within engineering), whereas the remaining 11 students were full-time students on-campus.

While the majority of students were from biomedical engineering (13 of the 19), a diverse group of disciplines were represented by the course participants (2 students were from Mechanical Engineering and 1 was from Industrial Engineering, Interdisciplinary Biomedical Sciences, Engineering Management and Leadership, and Interdisciplinary Engineering*, each*). 9 students were pursuing PhDs, 9 were pursuing a Master's Degree, and 1 student was pursuing a professional degree. 15 students were U.S. citizens and 4 were not. The sex distribution of participants was roughly 2:1 males:females with 12 males and 7 females. The participants represented a wide racial distribution; 11 students identified themselves as Caucasian, 5 Asian or Pacific Islander, 2 as African American, 1 as Hispanic, 1 as North African, and 1 as Middle Eastern (students could select more than one ethnicity).

**Quantitative Results**

The quantitative component of this study includes two distinct parts. The first provides descriptive statistics for the IRI and paired t-testing results of the pre-post scores along the Perspective-Taking scale of the IRI. The second part describes the perspective-taking category of the Ethics Transfer Case, alongside descriptive statistics of the pre- and post- scores assigned to students' submissions.

**Phase 4.1A: Interpersonal Reactivity Index (IRI)**

The IRI consists of four empathy sub-constructs as described in the literature review; (a) fantasy, (b) perspective-taking, (c) empathic concern, and (d) personal distress (M. H. Davis, 1983). While the focal point of this section is on the perspective-taking measure, we present statistics of the other sub-constructs describe where students were at along the other survey measures. Once we obtained the survey data, negative items were reverse-scored for analysis. We used SPSS Statistics 20 to analyze the data. First, we evaluated internal-consistency reliability for each set of responses prior to summing the items into their theoretical factor-structure. Next, we checked the mean difference scores between each factor for normality assumptions. Lastly, we used the difference scores to evaluate changes in students' empathic perspective-taking tendencies.

***Reliability of the IRI subscales***

As Table 4.4 shows, Cronbach's alpha for the Perspective-Taking and Empathic Concern sub-constructs were above the 0.70 threshold for acceptability for the pre- and post- course responses, whereas the pre-course fantasy scale was below the 0.60 threshold for minimal acceptability (DeVellis, 2011).

**Table 4.4**: *Original Alpha statistics for Interpersonal Reactivity Index subscales*

| | Perspective-Taking | Empathic Concern | Fantasy | Personal Distress |
|---|---|---|---|---|
| **Pre** | .813 | .808 | .578* | .608** |
| **Post** | .736 | .823 | .638** | .724 |

*Results are not acceptable, must be improved
**Results are minimally acceptable, should be improved if possible

The items in-between the 0.60-0.70 alpha range are 'minimally' acceptable, but still not highly reliable (DeVellis, 2011). Therefore, we checked to see if the reliability of any of these scales increased by removing one or two of the items from the survey. Table 4.5 shows an overview of these results.

**Table 4.5:** *Modified Alpha for Interpersonal Reactivity subscales if items were removed*

| Perspective-Taking | | | Empathic Concern | | | Fantasy | | | Personal Distress | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Item* | Pre | Post | Item | Pre | Post | Item | Pre | Post | Item | Pre | Post |
| *Q03* | .768 | .726 | *Q02* | .791 | .840 | *Q01* | .587 | **.714** | *Q06* | .566 | .648 |
| *Q08* | .818 | .670 | *Q04* | .795 | .795 | *Q05* | .471 | .470 | *Q10* | .442 | .619 |
| *Q11* | .765 | .661 | *Q09* | .772 | .788 | ***Q07*** | **.702** | **.694** | ***Q13*** | **.763** | .719 |
| *Q15* | .777 | **.758** | *Q14* | .763 | .809 | *Q12* | .433 | .546 | *Q17* | .506 | .703 |
| *Q21* | .783 | .691 | *Q18* | .807 | .770 | *Q16* | .489 | .562 | *Q19* | .573 | .686 |
| *Q25* | .801 | .731 | *Q20* | .773 | .811 | *Q23* | .495 | .573 | *Q24* | .543 | .689 |
| *Q28* | .796 | .684 | *Q22* | .775 | .780 | *Q26* | .522 | .581 | *Q27* | .478 | **.755** |

By removing one item from the fantasy scale (Question 7) and one item from the personal distress scale (Question 13) for the pre- and post- course responses, the reliability statistics were greatly improved. The only factor that was 'minimally acceptable' was the post-course responses to the Fantasy scale, as shown in Table 4.6.

**Table 4.6** *Alpha statistics for modified Interpersonal Reactivity Index subscales*

| | Perspective-Taking | Empathic Concern | Fantasy[1] | Personal Distress[2] |
|---|---|---|---|---|
| **Pre** | .813 | .808 | .714 | .763 |
| **Post** | .736 | .823 | .694* | .719 |

*Responses are only minimally acceptable
[1]Item 7 was removed
[2]Item 13 was removed

***IRI descriptive statistics***

Table 4.7 shows descriptive statistics for each of the subscales of the Interpersonal Reactivity Index. As shown by the mean difference scores, the Perspective-Taking scores improved the most ($\mu = 0.315$, $\sigma = .613$), followed by Empathic Concern ($\mu = 0.233$, $\sigma = .615$). The Fantasy scores slightly decreased ($\mu = -0.088$, $\sigma = .620$), whereas the Personal Distress scores decreased at the highest magnitude of all changes ($\mu = -0.423$, $\sigma = .586$).

**Table 4.7**: *Changes along Interpersonal Reactivity Index subscales*

| Category | Pre/Post | Mean | Std. Deviation | Minimum | Maximum |
|---|---|---|---|---|---|
| **Perspective Taking** | Pre | 3.55 | .706 | 2.29 | 4.86 |
| | Post | 3.87 | .562 | 2.57 | 5.00 |
| | Post - Pre | .315 | .613 | -.72 | 1.85 |
| **Empathic Concern** | Pre | 3.62 | .748 | 2.43 | 4.86 |
| | Post | 3.85 | .701 | 2.29 | 5.00 |
| | Post - Pre | .233 | .615 | -.43 | 1.86 |
| **Fantasy** | Pre | 3.34 | .630 | 2.00 | 4.50 |
| | Post | 3.25 | .646 | 2.17 | 4.17 |
| | Post - Pre | -.088 | .620 | -2.17 | .50 |
| **Personal Distress** | Pre | 2.61 | .740 | 1.33 | 4.00 |
| | Post | 2.18 | .654 | 1.00 | 3.17 |
| | Post - Pre | -.423 | .586 | -1.83 | .67 |

Table 4.8 provides an overview of the changes to each Perspective-Taking item. As this table shows, changes on specific items of this scale were highly variable. Only two of the items showed zero or very slight change (items 8 and 21) whereas all the other mean scores changed by at least 0.3 points corresponding to the 1-5 point Likert scale.

**Table 4.8:** *Overview of pre-post IRI Perspective-Taking responses item-by-item*

| Item | Pre-Course | | Post-Course | | Post-Pre |
|---|---|---|---|---|---|
| | Mean | Std. Deviation | Mean | Std. Deviation | Mean |
| 3. I sometimes find it difficult to see things from the "other guy's" point of view. (Reverse Scored) | 3.263 | 1.368 | 3.737 | 1.046 | 0.474 |
| 8. I try to look at everybody's side of a disagreement before I make a decision. | 4.211 | 0.631 | 4.263 | 0.872 | 0.053 |
| 11. I sometimes try to understand my friends better by imagining how things look from their perspective. | 3.368 | 1.342 | 3.895 | 0.809 | 0.526 |
| 15. If I'm sure I'm right about something, I don't waste much time listening to other people's arguments. (Reverse Scored) | 2.947 | 0.911 | 3.368 | 0.895 | 0.421 |
| 21. I believe that there are two sides to every question and try to look at them both. | 4.053 | 0.911 | 4.053 | 0.780 | 0.000 |
| 25. When I'm upset at someone, I usually try to "put myself in his shoes" for a while. | 3.316 | 1.003 | 3.684 | 1.003 | 0.368 |
| 28. Before criticizing somebody, I try to imagine how I would feel if I were in their place. | 3.684 | 0.820 | 4.105 | 0.809 | 0.421 |

***Testing IRI subscales for normality***

In order to perform t-testing along each of these sets of data, the mean difference scores must be approximately normally distributed (Howell, 2010). As shown in Table 4.9, the Perspective-Taking and Personal Distress scales were approximately normal, whereas the empathic concern and fantasy scales were approximately non-normal. This indicates that non-parametric testing procedures would be required to compare pre- and post- responses along these sub-constructs.

**Table 4.9:** *Shapiro-Wilk statistics for distribution of difference scores*

| | Statistic | df | Sig. |
|---|---|---|---|
| Perspective-Taking Mean Differences | .961 | 24 | .588 |
| Empathic Concern Mean Differences | .863 | 24 | .011* |
| Fantasy (modified) Mean Differences | .785 | 24 | .001* |
| Personal Distress (modified) Mean Differences | .980 | 24 | .941 |

*Scale is approximately non-normal ($p < .05$)

***Power analysis on IRI's Perspective-Taking scale***

Statistical power is the likelihood that the null hypothesis will be correctly rejected. Power is dependent upon sample size, the mean of the difference scores, the correlation between the scores, and the pooled variance. Cohen (1992) suggests 0.80 ought to be the threshold for statistical power in quantitative testing. Using SAS 94, this study found that the Perspective-Taking scale of the IRI had a power of 0.610. With the mean difference score ($\mu_{diff,IRI} = 0.315$), standard deviation ($\sigma = 0.613$), and correlation ($r = 0.552$) between pre- and post- scores being equal, approximately 29 students are needed to reach a statistical power of 0.80. The slightly lower statistical power found indicates there will be a greater likelihood that we will incorrectly reject the null hypothesis (e.g. commit a Type II error). In other words, if there was a significant change in students' self-report socres to Perspective-Taking scale ofthe IRI results, there is moderate chance that we will fail to detect it.

***Pre-post changes on IRI's Perspective-Taking scale***

Paired samples t-test compared students' pre-post course responses along the Perspective-Taking subscale of the Interpersonal Reactivity Index. This statistical procedure involves comparing the differences in scores from two related groups (the groups in this study are "related" as they are the same individuals). This statistical test provides a means to examine the difference between pre and post scores on perspective-taking subscale. The pre and post scores can be combined into one item called a difference score (Howell, 2010, p. 340). The following hypotheses were:

**Null Hypothesis 1a**: Students in the experimental group show no differences in their self-reported perspective-taking tendencies before and after the course.

**Alternative Hypothesis 1a**: Students in the experimental group show significantly higher levels of their self-reported perspective-taking tendencies after the course as compared to before.

The t-statistic determines the significance of the difference scores, calculated as:

$$t = \frac{\overline{D} - 0}{s_{\overline{D}}} = \frac{\overline{D} - 0}{\frac{s_D}{\sqrt{N}}}$$

Here $\overline{D}$ and $s_D$ represent the mean and standard deviation of the difference scores and $N$ is the number of pairs. For the perspective-taking scale the results were: $\overline{D} = .315$, $s_D = 0.565$, and $N = 19$. To test significance, the calculated t-statistic must be greater than the corresponding percentage point on the t-distribution for 1-tailed t-tests. For 95% confidence there are significant differences between pre-post scores using a one-tailed test with *df* = 18, *t* must equal 1.729 or greater. For 99% confidence, *t* must equal 2.539 or greater. The *t*-stat is as follows:

$$t = \frac{(\bar{D} - 0)}{\left(\frac{s_D}{N}\right)} = \frac{0.315}{\left(\frac{0.613}{\sqrt{19}}\right)} = 2.241$$

Table 4.10 shows an overview of these paired t-test findings along the perspective-taking measure. The other IRI items were not compared using t-testing as two of the measures did not meet normality assumptions, and as these measures were not the direct focus this study.

**Table 4.10**: *Paired t-test findings of Perspective-Taking scale from IRI*

| Measure | Mean Difference | Standard Dev. | Normalized Gain | *t*-stat | df | Sig. (1-tailed) |
|---|---|---|---|---|---|---|
| Perspective-Taking | 0.315 | 0.613 | 0.217 | 2.241 | 18 | 0.019 |

These paired t-test findings indicate that the null hypothesis be rejected in favor of the alternative hypothesis at the 95% confidence level. This suggests students' self-report scores showed significant increases in their perspective-taking tendencies as measured using the Perspective-Taking scale of the IRI.

**Phase 4.1B: Ethics Transfer Case (ETC)**

The second quantitative component of this study revolves around an Ethics Transfer Case (ETC) methodology that students completed at the start and again at the end of the semester. The ETC assesses changes along 5 categories of the reflexive principlism approach: (a) justification of the decision, (b) identification of ethical principles, (c) specification of the principles to the case, (d) perspective-taking, and (e) reflectivity. Hess et al. (2014) reported the initial phases of the validation process for the rubric applied to the transfer case responses. Appendix G describes the state of the rubric as applied to these results.

For this study, the primary focus was on the Perspective-Taking category of the ETC. Table 4.11 shows the scoring framework for this category. Responses were awarded anywhere between zero to three points for the first three items of the rubric, and one point for the final item. In other words, students could score anywhere between 0-10 on the Perspective-Taking component. Each of the five categories in the rubric were also on the 0-10 scale, so respondents could score a maximum of 50 points on the ETC assignment.

**Table 4.11**: *Perspective-Taking Category of the Ethics Transfer Case*

| **Rubric Item** | 3 points | 2 points | 1 point | 0 points |
|---|---|---|---|---|
| **Stakeholder Identification** | More than 3 stakeholders identified | 2-3 stakeholders identified | 1 stakeholder identified | No stakeholders identified |
| **Users' Needs** | 3 or more external stakeholders' needs are used to inform decision | 2 external stakeholders' needs are used to inform decision | 1 external stakeholder's needs are used to inform decision | No external stakeholders needs used to inform decision |
| **Other-Oriented Application of Principles** | The response contrasts how at least 2 stakeholders would weigh principles differently. | 2 or more principles are used explicitly as a basis to reason from another stakeholder's perspective | The response explicitly considers the values of external stakeholders | The response does not consider the values of other stakeholders |
| **Seeking feedback** | Does the response indicate a need for direct feedback from the stakeholders identified? (worth 1 point) | | | |

After several revisions of this rubric (as described in Hess et al., 2014), the perspective-taking category was continually simplified to make scoring of the submissions more reliable across coders. As a result, the final Perspective-Taking component includes a measure of how effectively the respondent (a) identified a wide range of users, (b) incorporated multiple users' needs into the proposed solution, (c) used ethical principles to guide perspective-taking, and (d) expressed a need for direct feedback from users.

Each of these components relate to potential *outcomes* of perspective-taking, rather than perspective-taking processes as described by M. H. Davis's (1996) functional model. For example, the incorporation of users' needs into the proposed solution relates to attributional judgments made by the respondent, which is dependent upon first identifying users. Likewise, empathic accuracy increases by seeking direct feedback from a user for whom a decision-maker approximates a need. The focus on using principles to guide perspective-taking is a key component of the reflexive principlism approach (Beever & Brightman, 2015), which the ETC overall seeks to measure (Hess et al., 2014).

***ETC inter-rater reliability***

After several iterations of the rubric to ETC responses, the rubric items were greatly refined as explained in Hess et al. (2014). In its stage as applied to this work (see Appendix G), four coders scored five responses. These coders included (a) the Teaching Assistant for the course in Spring 2014 who was a doctoral student in Philosophy and Communication at Purdue, (b) a doctor with a background in Philosophy who helped develop the reflexive principlism approach, (c) the leading professorate for the course and the lead P.I. on the NSF EESE grant around which this project revolved, and (d) myself, a doctoral candidate in the School of Engineering Education at Purdue University.

The level of inter-rater reliability was compared using a two-way mixed, consistency, average-measures Intraclass Correlation Coefficient (ICC, Hallgren, 2012; McGraw & Wong, 1996). The scores for each item and the perspective-taking category overall were in the excellent range, as shown in Table 4.12. These high ICC results indicate that there was minimal discrepancy between coders. The score that was lowest was on 'seeking feedback' (ICC = 0.80), and this was potentially due to the binary nature of this code and the relatively small sample size.

**Table 4.12**: *Inter-Rater Reliability for coding Ethics Transfer Case submissions*

| Survey Item | Intra-class correlation |
|---|---|
| Stakeholder Identification | 0.959 |
| Users' Needs | 0.954 |
| Other-Oriented Application of Principles | 0.862 |
| Seeking feedback | 0.800 |
| Perspective-Taking (Overall) | 0.938 |

***Quantized ETC Perspective-Taking descriptive statistics***

Table 4.13 shows a descriptive overview of pre- and post- average perspective-taking scores from the ethics transfer case on an item-by-item basis. As with the IRI, some items had no change, whereas others showed moderate increases.

**Table 4.13**: *Pre and Post Perspective-Taking descriptive statistics along the ETC*

| Category | Pre/Post | Mean | Std. Deviation |
|---|---|---|---|
| Stakeholder Identification | Pre | 2.421 | .692 |
| 3 points possible | Post | 2.421 | .607 |
| | Post - Pre | .0 | .745 |
| Users' Needs | Pre | 1.790 | .918 |
| 3 points possible | Post | 1.790 | .918 |
| | Post - Pre | .0 | 1.054 |
| Other-Oriented Application of | Pre | .579 | .607 |
| Principles | Post | 1.105 | 1.049 |
| 3 points possible | Post - Pre | .526 | 1.124 |
| Seeking Feedback | Pre | .579 | .507 |
| 1 point possible | Post | .737 | .452 |
| | Post - Pre | .158 | .688 |
| Perspective-Taking (Overall) | Pre | 5.37 | 1.978 |
| 10 points possible | Post | 6.05 | 2.571 |
| | Post - Pre | .684 | 2.689 |

***Normality testing of ETC's Perspective-Taking category***

As with the IRI Perspective-Taking difference scores, the difference scores between the Perspective-Taking category of the ETC was tested to see if they met normalcy assumptions. Calculation of the Shapiro-Wilks coefficient (coefficient = .968) showed that the scores attributed to Perspective-Taking category were approximately normal.

***Power analysis on ETC's Perspective-Taking category***

As with the Perspective-Taking scale of the IRI, the statistical power was calculated using SAS 94. The statistical power was found to be 0.153, a value much lower than the suggested 0.80 threshold indicated by Cohen (1992). With the mean difference score ($\mu_{diff,IRI}$ = 0.684), standard deviation ($\sigma$ = 2.689), and correlation (r =

0.324) between pre- and post- scores being equal, more than 100 students were needed to reach a statistical power of 0.80. The extremely low statistical power greatly increases the likelihood that we will incorrectly reject the null hypothesis (e.g. commit a Type II error). In other words, if there is a significant change in perspective-taking using the ETC results, there is a high chance that we will fail to detect it. In the future, many more responses will need to be evaluated to increase this statistical power.

***Pre-post changes on ETC's Perspective-Taking category***

Table 4.14 shows that there were not significant changes in students overall scores on the Perspective-Taking category of the ETC when comparing pre- and post-scores. The calculated *t*-stat was above 1.0, however, suggesting that the results were promising. Given the low statistical power, we will explore these findings in future applications of the Ethics Transfer Case methodology as the sample size increases.

**Table 4.14**: *Paired t-test of Perspective-Taking scores along the ETC*

| Category | Mean Difference | Standard Dev. | Normalized Gain | *t*-stat | df | Sig. (1-tailed) |
|---|---|---|---|---|---|---|
| Perspective-Taking | 0.684 | 2.689 | 0.148 | 1.109 | 18 | 0.141 |

PHASE 4.2: EXPLORING CHANGES IN PERSPECTIVE-TAKING TENDENCIES

The second phase of this study aligns concurrently with the first, and is therefore not directly influenced by the quantitative results reported in Phase 4.1. This qualitative phase explores the research question:

*From the perspective of course participants, which components of this engineering ethics course critically influenced the development of their empathic perspective-taking tendencies, if any, and what was the nature of this development?*

Rather than relying on statistical techniques, this component of the study explores which aspects of the 19 students' experiences were most critical in sparking perspective-taking development from the perspectives of the students themselves. As before, the low sample size is a limitation. Whereas before statistical power was the primary issue, here a salient concern is generalizability. Not only is there only 19 respondents, but these respondents participated in one course at one university. With this in mind, this qualitative component is primarily exploratory, and the findings will (ideally) inspire future pedagogical techniques embedded within research studies of a confirmatory nature.

**Critical Incident Technique**

The qualitative methodology implemented in this phase of the study is critical incident technique, where the objective is to identify and explore a set of critical incidents representative of changes in empathic perspective-taking (Butterfield, Borgen, Amundson, & Maglio, 2005; J. C. Flanagan, 1954; J. Hanson & Brophy, 2012; Woolsey, 1986). Woolsey (1986) indicated that scholars have used critical incident technique in a variety of domains for a variety of purposes, including but not limited to criterion development, construction of quantitative measures, and theory development. The exploratory nature of critical incident technique allows new theories to emerge from the participants' voices as opposed to the researchers' prior conceptions, existing scholarly literature, or cultural beliefs (J. C. Flanagan, 1954; Stano, 1983; Woolsey, 1986).

This methodology involves the process of sorting "a relatively small sample of incidents into piles that are related to the frame of reference selected" (J. C. Flanagan, 1954, p. 344). After the researcher sorts these piles, he or she creates tentative categories, and groups additional incidents into an existing category or embedded into entirely new categories. The researcher creates and refines a description or definition of the categories throughout the whole process. As J. C. Flanagan (1954) explains, "The tentative categories are modified as indicated and the process continued until all the incidents have been classified" (p. 345). As a final step, these categories are described narratively "with operational definitions and self-descriptive titles" (Butterfield et al., 2005, p. 483). According to Butterfield et al. (2005), the process most commonly utilized by researchers who have implemented critical incident technique since Flanagan's popularization of the methodology is "retrospective self-report" (p. 481) through interviews with participants, either in-person or by phone, and "by having individuals report from memory about extreme incidents that occurred in the past" (p. 478). Flanagan (1954) emphasizes that the methodology should be seen as flexible, and as such could be slightly modified according to the research phenomenon being investigated.

Critical incident technique has been widely used in education and in the last few years has enjoyed a growing popularity in engineering education research (e.g. see J. Hanson & Brophy, 2012; Johannisson, Landstrom, & Rosenberg, 1998; Walther, Kellam, Sochacka, & Radcliffe, 2011). As an example, Grant and Trenor (2010) used critical incident technique to study familial influences on students' decisions to pursue engineering as a major. They suggested key advantages of this methodology include focusing participants' discourse on specific phenomena of interest to the researchers through the implementation of a well-constructed interview protocol. They emphasized that this protocol must be phrased and delivered in a manner that gathers sufficient information to uncover *critical* factors of a student's experience.

In a separate study, Walther et al. (2011) applied critical incident technique to explore engineering students' formation of a professional identity when transitioning from students to practitioners. Through identification of critical incidents revealed during focus group interviews with 67 participants, they developed seven "competence clusters" or higher level categories related to the research phenomena. Walther et al. recognized the interpretive nature of their findings, and provided a holistic account of their research process alongside thick description of each cluster to enhance the credibility of their findings.

**Developing a Quality Framework**

As critical incident technique is a qualitative research process, quality considerations permeate all aspects of this methodology, including the development of the procedures to collect data, the analysis processes employed, and the reporting of the results. The researcher may attain quality through purposeful steps to ensure credibility and trustworthiness of the findings (Creswell, 2013; Krefting, 1991). Case and Light (2011) emphasized that qualitative researchers must vividly show their "research findings are rooted in contexts and persons apart from the researcher, and that they did not merely arise in the researcher's imagination" (p. 188). With this in mind, Walther, Sochacka, and Kellam (2013) suggested quality management should be used to focus on the research process as it "offers a way of thinking about research quality that is applicable to a wide range of settings, can incorporate and contextualize existing strategies, and, at the same time, acknowledges that quality cannot be defined or achieved as an absolute measure" (p. 628).

This section describes three key references used to develop a quality framework for this research study. The first is Lincoln and Guba (1985) who describe techniques for achieving quality when a naturalist paradigm (a type of interpretivist paradigm) underlies the research process. The second is Butterfield et al. (2005) who describes steps to ensure quality when using critical incident technique as a methodology. The last is Walther, Sochacka, and Kellam (2013) who offer a framework for seeking a series of validity types when conducting interpretive research in engineering education.

For Lincoln and Guba (1985), trustworthiness in naturalistic research is contingent upon four factors: (a) credibility, (b) transferability, (c) dependability, and (d) confirmability. **Credibility** is increased through *prolonged engagement* with the research phenomena and participant's context (which in turn opens the researcher to potentially influential factors), *persistent observation* (where the researcher focuses in detail on these influential factors), and *triangulation* (through usage of multiple data sources, methods, and investigators). *Peer debriefing* enhances the credibility of the findings. Here the researcher shares their thoughts with a disinterested peer in order to make implicit thoughts explicit. Another method is *referential adequacy* which involves using a separate set of data (e.g. videos, written text) as a reference to the key data. Lastly, *member checking* involves sharing the key findings with participants and seeing if the results resonate with the participant.

**Transferability** is concerned with the external validity of research findings. The researcher achieves transferability through providing a *thick description* of the research results with enough data (potentially even an entire data base) in order to allow readers to infer the transferability of the results to their own contexts. The researcher must ensure **dependability** for both the research process and research product. Lincoln and Guba (1985) use the metaphor of an *inquiry auditor* who authenticates that the process followed is satisfactory and attests that the data supports the results. **Confirmability** (which is aligned with but not equivalent to dependability) involves establishing an audit trail and going through five stages of an audit process with an inquiry auditor. These steps include (a) preentry, (b) determination of auditability, (c) formal agreement, (d) determination of trustworthiness, and (e) closure.

Butterfield et al. (2005) describe nine non-linear steps that may be used when using critical incident technique to ensure credibility. These steps (paraphrased) are as follows:

1. Independent extraction of critical events by someone other than the researcher
2. Participant cross-checking (also known as member checking)
3. Independent judges placing incidents into pre-developed categories
4. Exhaustiveness (e.g. sufficient incidents to where new categories no longer emerge)
5. Expert-checking of categories

6. Participation rate (relative number of participants who cited a specific experience)
7. Theoretical agreement (make guiding assumptions explicit)
8. Descriptive validity (record audio and transcribe, work from transcriptions)
9. Interview fidelity (ensure interviews are rigorous, not leading, and consistent)

Walther, Sochacka, and Kellam (2013) offer an engineering-education specific "$Q^3$ framework" that describes a series of validation modes and techniques for which a researcher can adapt his or her study. By working towards these validity types, the researcher will consciously be striving towards a valid qualitative study. The authors note, "While we do not advocate a rigid, mechanistic application of methods as an indicator of quality, the contextual, reflective adoption of methodologies and their explicit documentation and communication are a core aspect of the process-focused quality framework presented here" (p. 629).

Each of these types of validity are described in Table 4.15, along with strategies I have implemented to seek these types of validity in this study, pulling largely from Butterfield et al. (2005), Lincoln and Guba (1985), and the $Q^3$ framework from Walther, Sochacka, and Kellam (2013). A few of the strategies described involved the mixing of data from Phase 4.1, seeking to see if qualitative responses align with the quantitative results. These were ad hoc checks, however, intended to gauge the realistic-ness of findings, rather than inform the inductive developmenst of the categories. As mentioned earlier, quantitative results were not on hand when analyzing the qualitative responses.

**Table 4.15**: *Critical Incident Technique Quality Framework (Developed using Walther, Sochacka, and Kellam, 2013)*

| Validity Type | Type Description | Procedures for Attainment |
| --- | --- | --- |
| **Theoretical Validation** | Theories generated correspond with the social reality under investigation<br>*Q: Is this response really about the phenomena of interest?* | Explicit articulation of guiding research paradigms or worldviews; **Prolonged engagement** with the phenomena under study (although not letting prior understanding of this research phenomena limit analysis of the results) and the course context; Checking results against experts in the area under investigation and the scholarly research in the domain |
| **Procedural Validation** | There is a fit between reality and the theories generated<br>*Q: Were the right steps taken? Were any steps missed?* | Ensure **interview fidelity** through proper delivery of questions (e.g. avoid leading questions and allow participants to speak freely); Accurate identification of **critical incidents** that are truly critical through checking with expert qualitative researchers; **Independent coding** by a separate coder (Dr. Strobel) and myself; **Persistent observation** of the students' journeys through the course by sitting in and ethnographic observation of each class period, along with reading on-line submissions and discussion; Making **researcher biases** explicit and attempting to remove these from the findings through grounding interpretation in the data only |
| **Communicative Validation** | Social construction of knowledge is within the appropriate community(ies)<br>*Q: Is the terminology correct? Is the vocabulary misleading?* | Ensure interview quality is sufficient for accurate transcription; **Peer debriefing** of potential findings with my colleagues in Engineering Education to see if used nomenclature aligns with their understanding of vocabulary within the field; **Scholarly presentation** of the research findings and incorporation of **feedback** from the academic community, specifically, my dissertation committee members |

| | | |
|---|---|---|
| **Pragmatic Validation** | **Concepts generated must be realistic if situated within reality**<br>***Q: Do the findings pass a reality-check?*** | **Describe the participation rate or number of incidents grouped to a specific category to gauge strength of finding; Reference class interactions, written responses, group case reports, and quantitative survey measures to see if findings align with real events that transpired over the duration of the course; Examine whether results align with or contradict findings from the quantitative component; Seek exhaustiveness or data saturation to the extent possible** |
| **Ethical Validation** | The process is carried out with integrity and responsibility<br>*Q: How would I want to be treated?* | Notify participants that not all questions need to be answered if they feel uncomfortable; Make reported responses confidential through pseudonyms so these are not linked to the initial participant; Report real data as recorded and refrain from embellishing results that are ambiguous, uncertain, or only minimally supported; Make limitations and my own biases explicit |
| **Process Reliability** | Research process is controlled from confounding influences<br>*Q: Is the process dependable?* | Ensure **dependability** and **confirmability** through seeking feedback from my dissertation committee members (who act as **inquiry auditors**); Ensure (a) the criticality of the incidents, (b) establish whether my interpretations of the incidents align with others', and (c) provide **thick description** of results while giving voice to participants; In terms of **exhaustiveness**, ensure enough incidents correspond with a finding and explicitly caution if follow-up studies are needed to support a theme (which is generally true for all themes due to the low N) |

One component of the quality framework notes that making researcher biases explicit is important. While the goal is for rigor, inherently researchers have biases that impact the final results to some extent. The purpose of the quality framework is to minimize that impact. Nonetheless, the reader must recognize that I am a PhD candidate interested in exploring the role of empathy because I believe it is a core disposition for engineers to have when making ethical decisions – that is, decisions that are truly sustainable and socially equitable. Upon starting this investigation, I had minimal a priori presuppositions regarding *how* empathic perspective-taking would change as a result of participating in this course, if at all. The course was designed in such a manner as to hopefully influence the development of perspective-taking, so to some extent, our research team did embed course components that would hopefully *cause* increases in perspective-taking tendencies. Therefore, the reader may infer that I was *hoping* the course did influence perspective-taking tendencies. Hence, the quality framework is a means to ensure rigor and credibility by seeking validation of the process followed.

**Qualitative Data Collection**

The primary source of qualitative data in this study is end-of-semester semi-structured interviews conducted within one week of the students completing all other course assignments but before grades were due. Each of the 19 students who participated in the Spring 2014 engineering ethics course were awarded eight course percentage points for participating in these interviews. The interviews were conducted on-line using Skype and Call Recorder software. Due to this rigid timeline for these interviews, three separate interviewers were involved in the process: (a) myself, (b) a Communications professor/member of the NSF research team, and (c) a graduate student in the school of Communication to whom I described the course goals and context and trained to deliver the protocol. I conducted nine of the interviews and the other interviewers conducted the last five. The duration of interviews ranged from 32 minutes to 70 minutes with the majority of interviews lasting between 45-50 minutes in length. A professional transcription company with experience in social science research transcribed the interviews. The transcriptions did not retain hesitation remarks (e.g. "ums", "ers"), but the transcripts noted pauses of five or more seconds. I used MAXQDA11 to analyze these transcripts

Interviews sought to understand students' overall experience in the course. As a result, perspective-taking was not the sole research foci explored through analysis of the interview transcripts within the broader NSF EESE grant. As shown by the interview protocol in Appendix H, the interviews contained six primary sections, only one of which we explicitly labeled "Perspective-Taking". Nonetheless, for this investigation, I explored the entirety of the interview with only the perspective-taking research questions guiding the analysis. The perspective-taking interview questions were as follows:

- Has your ability or tendency to take the perspective of others changed as a result of the course? *In what way?*
- What components of the course helped you take the perspective of others, if any? *Can you provide an example?*
- To what extent did the perspective-taking activities at the start of the case influence your group's decision in the final case report along each of the cases?

[*provide explicit description of Stage 2 activities if students seem uncertain of which component this refers to, and re-ask*]

The interviewers used follow-up questions, including but not limited to those listed in italics above, to prod deeper into the students' responses. While the majority of students provided a positive response to the first perspective-taking question and were able to articulate some manner of change, some students indicated they did not feel as if their perspective-taking tendencies changed in any manner. Nonetheless, nearly all of these students responded to each of the follow-up perspective-taking questions. Due to the semi-structured nature of the overall survey, responses related to perspective-taking could be stimulated by initial or follow-up questions within any of the interview components.

While the direct reference of perspective-taking is potentially confounding or leading, this directness was intentional to ensure (a) students would explicitly talk about perspective-taking, (b) each participant was operating with a similar relation to the perspective-taking prompts, and (c) students' depicted examples would be in relation to the same phenomenon. This directness seems analogous with the procedures described by Flanagan (1954) and Stano (1983).

Table 4.16 provides an overview of individual student's demographic background, alongside pseudonyms used to seek confidentiality. Pseudonyms provide a means for the reader to relate to the individuals within this study. I chose names that I thought fit the individuals, but I hope that my naming methodology does not inspire any (mis)associations to the students. I removed race and discipline to protect students' identities.

**Table 4.16:** *Participant overview by individual*

| Pseudonym | Sex: | Major |
|---|---|---|
| Ashley | Female | Biomedical Engineering |
| Bakari | Male | Biomedical Engineering |
| Chi | Male | Industrial Engineering |
| Duman | Male | Biomedical Engineering |
| Erica | Female | Biomedical Engineering |
| Fred | Male | Mechanical Engineering |
| Gilia | Female | Engineering Management and Leadership |
| Hoshi | Male | Biomedical Engineering |
| Isabelle | Female | Biomedical Engineering |
| Jia | Male | Biomedical Engineering |
| Kirian | Male | Biomedical Engineering |
| Ling | Male | Biomedical Engineering |
| Mark | Male | Interdisciplinary Biomedical Sciences |
| Nicole | Female | Biomedical Engineering |
| Olive | Female | IDE with Biomedical Engineering concentration |
| Phoebe | Female | Biomedical Engineering |
| Rex | Male | Mechanical Engineering |
| Sammy | Female | Biomedical Engineering |
| Ted | Male | Biomedical Engineering |

## Qualitative Data Analysis

In this analysis I seek to explore two separate components of the primary research question, differentiated as: (a) potential *causes* of development in perspective-taking and (b) the *nature* of the change in perspective-taking. In this sense, the phenomenon investigated is students' *empathic perspective-taking* ability and tendency. Critical incidents provide the context to address the two research questions related to students' changes in this ability or tendency. Once a final set of critical incidents are identified and validated as "critical", these incidents become the context for performing thematic analysis, allowing themes to emerge inductively from the students' responses (Braun & Clarke, 2006). Each critical incident, in of itself, is used as the unit of analysis. I sorted these incidents into only one inductively generated theme. In order to properly implement the critical incident technique, the initial key question I explore here is, "What counts as a critical incident?"

### Defining criticality

Butterfield et al. (2005) describes critical incidents as "critical events, incidents or factors that help promote or detract from the effective performance of some activity or the experience of a specific situation or event" (p. 483). Walther et al. (2011) depicts critical incidents as "detailed accounts of real-world experiences of the participants" (p. 711). Flanagan (1954) and Butterfield et al. (2005) identified constraints for critical incidents, described as follows:

a) "By an incident is meant any observable human activity that is sufficiently complete in itself to permit inferences and predictions to be made about the person performing the act. To be critical, an incident must occur in a situation where the purpose or intent of the act seems fairly clear to the observer and where its consequences are sufficiently definite to leave little doubt concerning its effects." (J. C. Flanagan, 1954, p. 327)

b) "The criteria for incidents to be included in a study are commonly thought to be: (1) they consist of antecedent information (what led up to it); (2) they contain a detailed description of the experience itself; and (3) they describe the outcome of the incident." (Butterfield et al., 2005, p. 488)

For the purposes of this study, critical incidents are retained using the following criteria: any event in which the student portrays the equivalent of an 'a-ha' moment, meaning where a different frame of perspective or tendency to take others' perspectives 'clicked' as a result of some specific incident or set of incidents which occurred during the course. J. Hanson and Brophy (2012) suggest that once a critical incident is verbalized by a participant, it becomes the context of the interview and follow-up questions can further elucidate the incident itself. The research team did not implement interviews in this fashion, due to the multiplicity of research goals explored using these interview transcripts. Still, follow-up questions within the perspective-taking section were of this nature, intended to deeply explore the participants' reflective perception of any described incident.

**Critical incident identification**

In order to identify critical incidents, as a first step, I made several passes through the 19 interview transcripts. In this process, I employed a very general inductive coding process with categories emerging form the data, and more importantly, identifying anything that closely resembled a critical incident. After several passes, I identified 34 potential critical incidents from the interviews. A review of these, closely examining whether the incident corresponded with an actual *change* and deducing if this change appeared to be a result of the course itself, led to the elimination of thre of the potential incidents.

As a next step, I shared the 31 remaining critical incidents with two experts in qualitative research methods who had prior experience with critical incident technique to see if these incidents met the stated criteria for criticality. One expert (Dr. Strobel) identified three 'weak' critical incidents. The other expert (Dr. Kellam) identified four incidents as *not* critical and 10 incidents as 'somewhat' critical. This second expert's suggestion was to explore other portions of the transcript for each 'somewhat' incident to determine if there was additional information that may support the criticality of the incident, thereby providing referential adequacy as described by Lincoln and Guba (1985). After incorporating this feedback, I removed four incidents, retaining a total of 27 critical incidents for analysis.

**Qualitative Results Overview**

Thematic analysis of the 27 identified critical incidents led to the development of six themes along the first component of the research question, pertaining to the *cause* of change in perspective-taking, and five themes along the second component of the research question, pertaining to the *nature* of change. As themes emerged and were refined, I grouped each critical incident into the emergent theme that it best fit, although many of the incidents potentially could have fit under multiple themes. Therefore, identified categories are not mutually exclusive, although each theme was sufficiently different to warrant distinction.

Table 4.17 provides a title of the themes generated along each research question. These themes proceed in order from the theme with the most critical incidents mapped onto it to the theme with the least. By virtue of having the most critical incidents mapped onto them, the initial themes suggest a greater prevalence, but not greater importance. In this section, I do not make claims regarding the relative importance of any of these themes, nor is the magnitude of change explored. Phase 4.3 provides a 'mixing' of the qualitative and quantitative findings to validate findings generated here and to explore which incidents may have been most impactful for students.

**Table 4.17**: *Summary of interpretive themes*

| **A. CAUSE OF CHANGE** | **B. NATURE OF CHANGE** |
|---|---|
| A1. Sharing of diverse perspectives | B1. Open-mindedness |
| A2. Challenge of ethical decision-making | B2. Holistic perspective-taking |
| A3. Projection or self-oriented role-taking | B3. Principle-based perspective-taking |
| A4. Emotionally powerful experiences | B4. Worldview broadening |
| A5. Repetitive application of principles | B5. Social responsibility realization |
| A6. Cognitive dissonance | |

In the following sections, these themes were explored individually, with a thick description (Geertz, 1973) of each theme presented alongside exemplary quotes, these quotes being taken directly from the interview transcripts. I report the dialogue from the interviews directly and verbatim, with particularly indicative statements bolded to add emphases. Through this process, I give to the participants to allow the reader to directly interpret the provided passage for himself or herself, and to see if those interpretations align with my own. Further, this allows the reader to determine the transferability of any theme to his or her own context. This results section ends with a mapping of the themes between research questions, exploring which causes of changes led to which types of change according to my interpretations.

**Phase 4.2A: Causes of changes in perspective-taking**

This section presents the six inductively generated themes developed along the research question regarding the cause of change in students' perspective-taking tendencies in order of frequency count. Each theme includes a series of critical incidents presented alongside the theme's description. Each of the critical incidents portray specific experiences that led to some kind of change in perspective: be it the participant's general perspective-taking tendencies, their perspective on a specific ethical dilemma, or their receptiveness to novel perspectives.

***Theme A1: Sharing of diverse perspectives***

Throughout the semester, the sharing of diverse perspectives, in particular those that were surprising or largely dissimilar from one's own perspective, sparked a shift in a student's perspective or a change in their tendency to take others' perspectives. The process of sharing diverse perspectives commonly involved a two-way discourse. In order for some form of change to occur, the student generally played the role of a receptive listener. Additionally, in most incidents, the student was an active participant in the dialogue, internally reflecting and juxtaposing their own perspective against another's perspective or others' perspectives. This process occurred throughout different activities (e.g. classroom discussions, asynchronously through on-line discussion posts, working through group case reports). The pervasiveness of interactions with others throughout all aspects of the course might indicate why this theme was the most frequent of all the themes pertaining to this research question, with 8 of the 27 critical incidents most closely fitting this category.

In this initial critical incident, Kirian does not indicate which case study from the course he is referencing. He appears to suggest he had a recurring experience throughout the semester, where there was alignment between his group members' prioritization of the principles but discrepancies in their specification of the principles. These discrepancies were particularly eye-opening for Kirian.

> ***Interviewer****: My question is: do you feel that you might be better equipped to consider other perspectives, or take the perspective of somebody else, as a result of what you've been exposed to in this course?*
>
> ***Kirian****: Oh, absolutely. To give you an example: when we saw every test case, we were asked to rank the four principles. Oftentimes, we would all come up with the same ranking. However, the justification for ranking them in that order was often very different. Even though I would rank justice, just to give you an example, justice number one for X and Y reason, somebody else would rank justice number one, but it was for a different reason. Understanding that and looking at those answers and figuring out,* "***Oh, this is how I'm looking at it, but this is how someone else is looking at it as well.***" *It opened my eyes*

*a little bit because a lot of the things that were written when we were ranking these principles* ***came from experiences that I hadn't had****, even though we're all engineers.*

In this second critical incident mapped to this theme, Hoshi suggested that, in general, "listening to the in-class discussion" motivated him to take the perspectives of others. After a follow-up question, Hoshi describes a specific experience that occurred during the initial course case study on Tissue-Engineered Heart Valves, where students had to choose between one of two pediatric heart-valves to move forward. As I sat in on the class discussions, this initial case prompted much discussion as each individual student verbalized and defended their position. Hoshi initially selected the device that would have a wider distribution rate but a higher failure rate, but the sharing of perspectives challenged his initial decision.

***Interviewer****: You mentioned you saw [pause] – I'll just ask, what components of the course, if any, helped you take the perspectives of others?*

***Hoshi****: Listening to the in-class discussion. I really enjoyed hearing what other people's opinions were. The in-class discussions. [Pause] Just* ***listening to other people's opinions really opens other people's eyes. Certainly my eyes****, for instance, of things I never thought about, or things like that.*

***Interviewer****: Can you provide any specific examples?*

***Hoshi****: Oh, of a time where my opinion was different?*

***Interviewer****: Sure.*

> ***Hoshi****: Going back to the first case, you're so dead set on I think. I think that you should just help as many people as possible with this one device. I can't remember what it was.* ***Then when you hear some of the arguments on the other side, you get this completely contrasting idea. It starts to build onto you.*** *You might change your mind. That happened to me. That would be an example of just listening to other people's perspectives and opinions gave me new information that made me change the way I thought, too.*

Another participant, Olive, noted that out-of-class discussions with a specific classmate were particularly influential for changing her perspectives on the cases, but referenced the in-class discussions for bringing to light "really novel" perspectives that she had never before considered. Olive was a distance student, meaning she watched the in-class discussions and then shared her thoughts on the ethical issues discussed in-class post-case in the online forum.

> ***Interviewer****: Can you recall a time in which discussing the course material with somebody in class influenced your perspective or your thinking about the case or ethics in general? Can you give me an example?*
>
> ***Olive****: Yeah. A lot of the discussions that I had, specifically between myself and another classmate, usually it was that we were in agreement.* ***There was at least a couple of cases where somebody talked about something in the class that I wasn't there for, where it really gave me a new perspective****. Whether I disagreed with them or not, specifically with that tissue engineering valve case, I was on the side of basically taking the tissue engineering valve*

> *model that would be more widespread and that more children would have access to, as opposed to the higher quality [device] that the old people would have access to.*
>
> *Somebody brought up the concept of, well, if you built something of a better design, even if it wasn't available to as many people, you might instigate other companies to build that good of a design with that high of a quality that could be available to more people.* ***I had never even thought of the concept of some other company – a competitive company building something similar.*** *That was I thought a really novel idea. It didn't necessarily change my overall decision in the end,* ***but it definitely made me think about it in a different perspective.***

***Theme A2: Challenge of ethical decision-making***

Critical incidents fitting this second theme suggested students experienced changes in their perspective-taking tendencies due to the challenge of the case studies they worked through during the course, especially when students became aware of an ethical dilemma they were previously unaware of, and where the 'correct' answer was blurry or uncertain.

In this first incident, Gilia discusses the difficulty working through "grey area" issues, and the types of questions she felt inclined to ask to work through these dilemmas. She verbalizes a general tension she felt when working through some of the case studies: making money versus good intentions. Her specific example is from the Osteopenia case study, where patients were diagnosed with a potential disease called Osteopenia, although the consequences of the disease were wholly uncertain (e.g. further bone loss could lead to Osteoporosis, or Osteopenia could be of no consequence). Despite this uncertainty, physicians prescribed patients drugs to alleviate potential problems. Results of clinical studies (presented to students towards the end of the case) indicated that usage of these drugs was having a detrimental impact on many of the patients who used them.

***Interviewer****: Did you find anything surprising? Were you like, "I thought ethical decisions looked like this and they really look like this"?*

***Gilia****: I experienced that with one of the cases. That was the one about the pills. I don't know if you're familiar with the cases, but –*

***Interviewer****: Yeah, I am.*

***Gilia****: There was one with the whole Fosamax [a drug that prevented further bone density loss] thing, and how they made something become a disease or whatever. I think that case was different in that you really had to look to see where were the lines between, "This is ethical and this is okay or this is breaking a law," and things of that nature.* ***It was more grey area with that case. [Chuckles] it was more grey area with that. I was surprised by that.***

***Interviewer****: When you say there was more grey area, how did you then respond to that as an ethical challenge?*

***Gilia****: Well, by trying to learn as much background as possible. It just made me think, "Is this how all pills are pushed out on the market?" [Chuckles] That's kinda scary.* ***Part of it was just trying to better understand, "Who are the stakeholders? What were they doing? What was their main purpose?***

> ***What was the sole purpose of what they were doing?"*** *At some point, it sounded good, and it had good intentions. At other points, it's like, "Okay, now it's just about money. That's not so great anymore."*

In the next incident, Chi discusses a general shift in his perspective-taking tendencies throughout the semester as a result of working through each of these cases. Here, Chi references the novelty of thinking from the perspective of the largest corporate entity involved in a case, and how this pushed him to think of the ethical dimensions of the cases differently, which in turn added a layer of complexity to his group's final two case reports.

> ***Interviewer****: Can you recall or think about any instances where your discussion with someone else – could be in-class, it could be outside one of these other areas you identified – influenced or really changed your understanding or perspective about ethics in general?*
>
> ***Chi****: [Pause] Could you remind me what the third case was about?*
>
> ***Interviewer****: Was that the osteopenia, osteoporosis case?*
>
> ***Chi****: [Pause] That was one case where I hadn't really thought about the drug company perspective because there was so much focus on the patient. Becoming so easy to label MERC [the drug company] as bad that it was –* ***that's where my ethical perspectives started to change or really think about even the big, bad companies****. By the time we did the fourth case with BP, I was already thinking about what BP's perspective is.* ***That's where I started***

***to notice a shift. I was pushed by the class discussion and some of the portions of the report on case three [on osteopenia].***

In this next critical incident, Ashley first discusses what she felt like was expected for students to get out of the course, and it is not entirely clear whether she internalized any of those expectations. At the end however, she grounds here explanation in a real example from the course, making a reference to the uncertainty she experienced (and was still experiencing at the time of the interview) in coming to a decision in the tissue engineered heart-valve case study.

***Interviewer****: [Pause] In general, with the course, which aspects were most challenging, specifically in regards to your thinking or reasoning about ethics?*

***Ashley****: Well, sometimes you go into classes like this, and you want that straightforward process of finding an answer. We learned in the course that a lot of times, an answer isn't clear, and an answer always has drawbacks associated with it.* ***At the end of the day, it's always about balancing the benefits versus the risks. It's also about recognizing that different stakeholders have different gauges in terms of acceptability of risk, and different risks.*** *Trying to find that common ground that is either (a) abiding by a clearly recognized driving principle, or (b) is compromising the different stakeholders' needs, and wants, and risks, and that there. Even though we got some very useful tools, we recognize that it's not always clear cut. It doesn't always lead you to one answer.*

***Interviewer**: Sure. Are you referring to in your group reports, you recognized this challenge and how did you—*

***Ashley**: Yeah, especially in that heart valve case. Either I really – to this day, I don't know what the right answer is for that one, 'cause I'm very – I like quality. If you're gonna give it a go and you wanna have a heart, let's give 'em the best thing. Then again, it's like, "Well, doesn't everybody deserve a fighting chance? At least give 'em the chance to live."* ***That one there, it's still troublesome for me****.*

***Theme A3: Projection or self-oriented role-taking***

During the second (and sometimes the fifth) stage of the pedagogical framework used in the course, students were primed to think from the perspective of a specific stakeholder or subset of stakeholders. This act of projection, or self-oriented 'role-taking', served as a catalyst to get students to literally try on the perspectives of stakeholders in a manner that many students expressed as a novel experience.

In this critical incident, Hoshi discusses how his group used projection as a tool in their group case reports to justify their decision from the point of view of stakeholders involved in the case. In this critical incident, within the context of the Deepwater Horizon oil spill case study, Hoshi first alludes to the role of sharing perspectives amongst his group members in coming to a decision, and then indicates that this led to the realization that sometimes there doesn't exist a clear-cut "right" answer. He ends by explaining how the individuals in his group each imagined they were in the shoes of a different stakeholder, and they used that frame of mind to reason through the case from multiple perspectives.

***Interviewer****: Do you think this process was effective for helping you learn the case material? This process your group used?*

***Hoshi****: [Pause] Yeah. I thought the reading, the videos on YouTube videos, and then the class-discussion, I think those were the most effective ways of teaching the material. Well, teaching the case studies, I guess. [Pause] Actually, bouncing off all these different opinions and different perspectives from the students, from your group members, that was really educational. That was really beneficial. In terms of writing the case reports and then doing the reflection, and going through the group members' different opinions, that was a very educational experience.*

***Interviewer****: Do you mean in terms of changing your thinking about ethics in general, it was effective at that?*

***Hoshi****: Not changing my ethics, but just changing [pause] or* ***understanding that there isn't a right view point. There are very interesting and very valuable viewpoints that other people bring to the table.*** *It's forced upon when writing these reports, I guess.*

***Interviewer****: What do you mean it's forced upon?*

***Hoshi****: For instance, the last case study, we all took a certain perspective. [Pause] We forced ourselves on that particular perspective on how we would make the decision on whether to engage in the oil drilling in the Gulf of*

*Mexico. [Pause]* ***That forced perspective [pause], whether you wanted that – whether that was a natural perspective for you or not, you were forced to think about it in a different way.***

*Then you would see. Let's say you had a perspective that you naturally were inclined to, but you didn't write about that perspective.* ***You would see how another student would've written that perspective and gained more insight into what you originally thought, or a totally different insight to what you originally thought****. That's why the group exercises, and group discussions, and group writing was very effective.*

In the next critical incident, the interviewer directly asks about the influence of projection or role-taking activities on the group's case report. The respondent, Isabelle, describes how the course participants tended to become advocates for their chosen stakeholder, lobbying for a decision from that perspective almost as if they had become the representative for that specific group of stakeholders. Isabelle elucidates how these activities influenced one of her group's reports.

***Interviewer****: Usually, the cases had a perspective-taking activity towards the beginning. To what extent do you think those activities, when you had them, influenced your group's decision at the end in your group reports for each case?*

***Isabelle****: What you mean by is if we were told to take different perspectives, arguing through that, did that change people's minds? Is that what the question is?*

***Interviewer****: Sure.*

***Isabelle****: That happened on the last two, 'cause we came in, and we were all really on different pages. Then we started talking about – 'cause everybody had to pick a stakeholder, especially in the last one.* ***People were advocating for their stakeholders. It was interesting in that when they were advocating for their stakeholder, that brought up other arguments maybe for a different stakeholder's perspective more than the one that they were trying to argue for****. For example, in this last case, we had somebody as a representative of an engineering firm for the oil rig designers and builders.*

*This person was saying, "If we don't keep expanding drilling and we stop building these rigs, all these professional people are gonna lose their jobs." That brought up the fact of, "Well, if there's more oil disasters, all these other downstream people are gonna have their jobs impacted as well." The impacts of that job loss is probably greater than the job loss that would be experienced by this niche industry.*

*Then we went even further with it and started discussing how not only are the job losses greater for these other stakeholders, but this niche industry could probably retool itself and support other energy initiatives in that the skill sets are probably very similar. They would probably be able to bounce back much better even than anyone else if that happened to them. Through that process, they brought that other person on board with going the opposite direction of what they had originally thought.*

***Theme A4: Emotionally powerful experiences***

Some of the course content or course experiences students found to be particularly powerful emotionally. In these experiences, students thought about the best course of action in a novel manner. For example, in this first passage, Sammy expresses her shift in perspective when working through the Osteopenia case as a result of thinking about the perspective of a misdiagnosed patient. From my class observations, Sammy tended to be quiet and perhaps a bit shy female student who did not commonly speak up in class unless called upon.

> ***Interviewer****: Can you recall a specific time where your discussion – it could be in-class or with your group or even online posting – where that discussion with someone really strongly influenced your understanding or perspective about ethics in general?*
>
> *[10 second pause]*
>
> ***Sammy****: On the osteoporosis case, one of the big influential pieces for me was when the woman was diagnosed with osteopenia and had to start taking drugs. When she had been healthy, and she'd been a runner, and lived her life.* ***Then after getting that diagnosis that was maybe not actually justified, that it really changed the way she lived and worried about herself. I don't – that was a big – that really brought the stakeholders to the forefront.***
>
> *The drug companies are making more money. People aren't necessarily having to pay a lot for the drug if they're insured. It's not just that this diagnosis isn't necessarily life threatening, but that it made someone worry.*

*Really thinking about all of the effects that something could have on the different stakeholders. That really happened in that case.*

In this next critical incident, Gilia alludes to the first case study on tissue-engineered heart valves. Within the passage, she offers a quote from the perspective of a parent of a child who needed a heart valve replacement. Thinking from this perspective, she suggests, makes the case "more emotional" and the stakeholder perspectives "stronger". This passage seems to indicate that the emotionally relevant consequences for a specific stakeholder channeled her to think from the perspective of that specific stakeholder who had high stakes in the outcome of the decision. This suggests that in situ, Gilia was primed to think from this stakeholder's perspective, but it is unclear to what extent students transferred this tendency outside of the case context.

***Interviewer****: What specific components of the course do you think helped you take those different perspectives of others, if any?*

***Gilia****: You said what about the course? Sorry. [Chuckles]*

***Interviewer****: What components of the course, or what specific –*

***Gilia****: For one, when we had to write each report, we had to bring in the different perspectives. That definitely helped. The last report was good, because* ***we all had to come be someone else****, in a sense.* ***We were forced to not think about what you would naturally decide or want. You had to say, "Okay, if I was coming from this person, what would they think? How would that affect them?"*** *That was a good roleplaying activity.*

> ***Interviewer****: To what extent would you say the perspective-taking activities at the start of the case influenced your group's decision in the final case report along each of the cases? [10 second pause]*
>
> ***Gilia****: [Chuckles] It definitely played a role. It definitely played a role. Yeah. I'm trying to go back in my head to cases and what we thought. [Chuckles] It definitely played a role. It varied by case, honestly. It varied by case. In taking perspective, we had two healthcare cases.* ***Many times, that one was a little more emotional. I think in taking the perspective of a parent or someone like that, "Hey, my child needs a valve." [Chuckles] That made it – those perspectives were stronger I think. "Hey, this is my son. They're gonna get what they need. I don't care about what valves."***

***Theme A5: Repetitive application of Reflexive Principlism***

Throughout the course, students justified their decisions by balancing stakeholder perspectives against the four principles of beneficence, non-maleficence, justice, and respect for autonomy. This 'reflexive principlism approach' challenged students to think about the cases with a specific set of ethical principles in mind. In this first critical incident fitting this theme, Isabelle describes how she developed this approach through the course, and she ends with an example of how she applied the framework in her own practice. Isabelle was a distance student who worked full-time while completing the course work and who, according to her, "had a lot of ethics training, both in undergrad and in working" prior to this course.

***Interviewer****: Before, you were mentioning it helps you take different perspectives and stuff. I was wondering if you could explain what you meant by that.*

***Isabelle****: [Pause] Let's see. [Pause] For example, maybe I'll put it in context of a situation. I found the case, I think it was the third case that we did, about whether or not it would be ethical to produce the bone scanner that was going to diagnose osteoporosis. It was interesting to have it grouped out, all the different considerations you would need to make in a decision like that, whereas how does it impact society, but how does it impact the patient themselves, or the doctors? What's good for the company for MERC, or the company that we were supposedly working for, which was the manufacturer of the scanners.*

*It was interesting to see how they fit in with those principles.* ***The fact that you could use those principles to categorize all those different stakeholders and figure out, if you had to rank whose perspective was most important, how would you do that?*** *That's what you're doing by ranking those principles and then putting the stakeholders into groups, based on the principles. I don't think I'm doing a good job of explaining this. I guess I don't really know. [Chuckles]*

***Interviewer****: You're fine.*

***Isabelle****: The best way to describe it was, just in what I do every day for a living, I consider the patient. I have to consider regulatory impacts of what I*

> *do and consider financial impacts of the company I work for, and consider the impact of what I do versus my own career. Those are always things that you're juggling.* ***It was interesting to take those different stakeholder perspectives and then group them versus the principles. Then you have a process. If you rank those principles, you start to figure out which stakeholder is really the most important in the case. It helps push you towards a decision.*** *That's maybe the best way to describe it.*

***Theme A6: Cognitive dissonance***

When students had the experience of being one of a few or the only individual supporting a decision, they experienced a form of cognitive dissonance, reasoning that if they were alone or in the minority defending a specific decision they must not be fully grasping some component of the problem. This dissonance caused students to look for a new perspective to consider as they tried to reason through their surprise in that they were alone or in the minority in their decision. This theme only had two critical incidents mapped onto it, and both of these incidents were from international students.

In this first passage, Duman describes his general surprise when the majority of students would defend a particular position that contrasted with his own. As I sat in on the classroom discussions, I remember watching these interactions recur multiple times, where this student would be defending a minority stance, and he would sometimes appear frustrated. In some instances, he would have slight successes, bringing one or two students onto his side of the argument. In this passage from the interview, he discusses how his choice in the heart valve case, which was to go with the device that could be distributed more broadly (the modular valve unit, or MVU), contrasted with the majority of other students, and how he found this to be surprising.

> ***Interviewer***: *You mentioned taking in perspectives of others earlier. Just in general, do you think your ability or tendency to take the perspectives of others has changed as a result of the course?*
>
> ***Duman***: *Yes.*
>
> ***Interviewer***: *Can you maybe articulate in what ways specifically?*
>
> ***Duman***: *[Pause] Not specifically.* ***It's just a general tendency now.*** *That's because of the long discussions we had.* ***I sometimes am surprised by the different positions people will take. That itself is motivation to accept other perspectives. In the first case, it was surprising to me that people would make the other decision.*** *That had a side effect of accepting, at least, other people's perspectives, even if it's completely different from mine.*
>
> ***Interviewer***: *Sure. [8 second pause]*
>
> ***Duman***: *Does that answer the question?*
>
> ***Interviewer***: *It does. I was trying to think of a follow-up question about the first case. That was the heart valve case. What perspectives or positions were surprising? How did you react either internally or externally?*
>
> ***Duman***: ***Yeah, I was surprised by the decision which was made [which was the THS – the more efficient device with a much lower distribution rate], because for me at least, it was pretty clear that MVU was the ethical choice.*** *[Pause] It wasn't perfect, but it was the ethical choice. People would go with*

*the perfect, although the statistics were [pause] different, the statistics – the success statistics of the two options were completely different. I thought about it for a day, and then forgot about it. It was surprising.*

The second critical incident underlying this theme is from Bakari, an international student who was not hesitant in sharing his perspectives throughout the course, and who seemed to internally struggle during the class-discussions when the case discussion involved a concept he did not fully grasp or he was defending a position where he appeared to be the lone supporter. Before this quote, Bakari explicitly states, "Sometimes I see some people – some student, not all of them, voting for something. It doesn't make any sense." He revisits this point in his reference to group discussions outside of class when working on the team case reports.

***Interviewer**: [Pause] Do you think that your ability to take other perspectives has changed as a result of the course?*

***Bakari**: Yes. Yes, it does. Again, the same case, case three [the osteopenia case]. When I say all the students against people, against – I think I was the only student who was –* ***I start saying to myself, that's impossible to be I'm the only right and the rest are wrong. I start looking to other, the other people perspective, opinion, things like that. That taught me to do that even in normal life, not only in the, in this case, in the class.***

***Interviewer**: What did you pick in case three, and what did everyone else pick?*

***Bakari**: My group?*

*Interviewer: Yeah.*

***Bakari**: My decision was, yes. We are going to fabricate it [the bone scanner device] if they send it to us.* ***I changed my mind the last minute to go halfway, because there are four of them*** *[supporting the other decision], [and they] quite don't agree about making it.*

**Phase 4.2B: Nature of changes in perspective-taking**

This section transitions to my interpretations of the nature of change in students' perspective-taking tendencies using the same set of 27 critical incidents. This section presents five inductively generated themes along the research question pertaining to the nature of change in students' perspective-taking tendencies in order of frequency count. As in the last section, each theme has a series of critical incidents presented alongside the theme's thick description. It is the same subset of critical incidents, but I primarily report critical incidents not presented in the previous section.

***Theme B1: Open-mindedness for ethical decision-making***

As a result of participating in the course, students became more open-minded and had a greater willingness to incorporate others' perspectives into their own ethical decision-making process. This theme was by far the most pervasive in this category, with 11 of the 27 critical incidents grouped here. In this first example, Ted discusses the necessity of having an open mind when working through the ethical challenges presented during in-course interactions.

***Interviewer**: What aspect of the course do you think was most challenging to your thinking or reasoning about ethics?*

***Ted**: [Pause] It was probably had to be the in-class discussion. Then you're – when you make an assertion and then it's disputed, you're not protected by the wall of the internet. You don't have time to think about and make a calculated response. You really need to be ready and own the way you feel about something. Also, **at the same time, have an open mind and be ready to accept the other opinions and work through it together**. That was probably the most challenging portion.*

***Interviewer**: This is tough, but can you give me a specific example of a time that happened?*

***Ted**: Sure. This is going back to the first case. A lot of this happened I think for everyone in that one, because again, it was so divided.*

***Interviewer**: That was heart valve, right?*

***Ted**: Right, and the utilitarian versus individual stuff. In that one specifically, was you found a lot of the – one of the divides that was most noticeable was that people who had lived internationally, say growing up for many, many years tended to tend toward the utilitarian side. Just based on what they had grown up with, and seen, and been a part of. People who had lived here and had been reasonably well off and had access to all the medical care they could ever need, tended toward the individual rights side. **That was a really interesting argument I think that came up and really helped me think through the case in a different way**.*

***Interviewer**: When you realize that something that you thought was being challenged, how did you respond to those challenges in your thinking?*

***Ted**: Most of the time, it was try to think of where they're coming from with that challenge. That's all you can do, 'cause like I said before, everybody in the room there is a smart person. They're all prepared for this and know just as much or more about ethics than I did.* ***The best thing for me that I could do is accept and think about why they think that way, and take it forward and see if it's changed the way that I think****.*

In another quote, Chi discusses how thinking from the perspective of an oil executive led to new insights on the case, even humanizing the "evil" corporate enterprise. Through this act, Chi began to recognize unique needs and challenges individuals representing these entities must work through, and realized that these individuals likely prioritize the principles in a manner different from most other stakeholders involved in a case due to their distinct perspective.

***Interviewer**: Do you think your ability or tendency to take the perspectives of others has changed as a result of the course? In what ways?*

***Chi**: [Pause]* ***Just putting yourself in other people's shoes can be really difficult****, especially since people are generally more self-absorbed nowadays with their phones and taking selfies and whatnot. [Chuckles] I don't take selfies by the way, just saying. [Chuckles]*

***Interviewer**: I took one once, actually, just 'cause my friends were talking about it. It felt strange. Just once though. [Chuckles]*

***Chi**: [Pause] Especially with this last case, the BP deep water horizon, the oil rig perspective or the oil executive perspective is something that's really I felt forgotten. Even though I wasn't assigned to take that perspective, I was assigned to the U.S. Marine Life Preserve perspective, thinking about the oil rig executive perspective was really instructive. Their principles were prioritized differently. Once you begin to see—they're not necessarily evil. Yes, they made a mistake.* ***I'm sure they feel just as badly about it as other people do, that once you begin to think about the human side of it, they also have some stake in it. It's just opened my eyes a little bit more to that.***

In this next critical incident, Kirian discusses his experience working through a case where he was on the side of the majority, and how the one student who was in the minority swayed his own perspective on an issue. This specific instance brought to my mind the movie 12 Angry Men, where one jury member of a murder case slowly convinces the other jurors there may be reasonable doubt surrounding the guilt of the defendant on trial.

***Interviewer**: Can you recall a time when, as a group, you had perhaps a split decision on how to approach something? Can you walk me through? What was the process by which, did you ever reach consensus? How did you work through that quote, "split decision"?*

***Kirian**: Yeah. I guess in general, as a group, we had very similar answers. For the most part, we ended up not resolving conflicts, but mostly justifying why most of that half-fence answers. There was, however, one time – this was* *on case number one –where there was a conflict. One of our group members, because of her personal experience and the type of work that she does, was very – she had a very strong opinion about, perhaps, the influence that, say, a marketing group may have in the release of a medical advance for FDA approval.*

*It was almost four against one in this instance, where this person had a very strong opinion about what she was saying. None of us, the four of us, didn't feel like that. She, nonetheless, made a very strong point. We worked through these – it was a series of comments going against her view. At the end of the day with all the collaboration we had and all the comments that we ended up writing and reading about each other, that decision or that point of view actually made it into our final paper.* ***It was – I didn't see it.*** *If I had that comment in front of me again, I would probably go against it.*

*At the end of the day, the arguments that she was able to make, I can find a better way. It was sort of like you fault that piece of information in which, looking back, it may have contributed to us getting a high grade on the paper because it was coming from a different perspective. It was coming from an experience that myself as an engineer do not have; neither did the other ones. [...]* ***She was able to see a different point of view that never was realized.*** *It was a point that we delayed probably through the end, for a very – to the last minute when we had to turn in that paper.*

***Theme B2: Holistic perspective-taking***

This theme suggests that as a result of participating in the course, students developed a tendency to holistically include stakeholders into their ethical decision-making process. This may have involved increasing the breadth of stakeholder perspectives included in their final decision on a case or the individual student's own level of understanding of one or more stakeholders.

In this initial critical incident, Mark discusses his uncertainty in prioritizing stakeholders within the Deepwater Horizon case study, in particular due to the "broad" scope of stakeholders included, particularly when Mark identified the environment as a key stakeholder.

> ***Interviewer****: How did your participation in the classroom discussions, like you were talking about before, specifically help you develop your thinking about ethical concepts?*
>
> ***Mark****: [Pause] Yeah. I felt like my personal participation could have been – it could have been greater. [Chuckles] There was just something about the classroom dynamic where I didn't end up participating as much as I [pause] wanted to, for some reason. I'm not exactly sure why. To answer your question, in terms of [pause] how my participation formed, mostly, I just really enjoyed hearing other people's perspectives. There were just some very reasoned arguments for [pause] –* ***for example, in the oil rig case, we had a good discussion about who was the primary stakeholder****.*

*We had this huge environmental disaster. At the same time, there was 11 people killed by an explosion on the oil rig. We don't know – at the same time, it's an environmental disaster, and we don't know the full extent of the damage done, or how long that damage will last for. [Pause] In class, we just had a very good discussion about [pause] how this is a unique case, I guess, in that regard, because* ***we don't know how to prioritize the stakeholders there****. It seems like [pause]* ***the environment is such a broad term. We could say that's marine life, the aquatic species, the ocean, but it's also inextricably linked to the people that surround that area****.*

***Theme B3: Principle-based perspective-taking***

This theme indicates that after working through a series of case studies, students tended to use principles to guide their perspective-taking, perhaps as a means to identify new stakeholders, or perhaps to compare, contrast, and balance conflicting stakeholder values. In other words, students used the reflexive principlism approach to reason from other stakeholders' perspectives.

In this first critical incident, Isabelle suggests that her perspective-taking tendencies did not change (she felt she already "naturally" took others' perspectives, although her scores on the perspective-taking scale from the IRI indicate a moderate increase). What did change, according to her, was that she now had a framework for thinking from novel perspectives. She gives an example of how she used the principles to identify new patients, and to think about their position within the osteopenia case study.

***Interviewer**: You talked a little bit about perspective-taking. What components of the course do you think helped you to take others' perspectives, if any?*

***Isabelle**: I do that naturally, but going through the principles – what I did a lot during the class, which'll show you how unfamiliar I was with these concepts, but throughout the class, I found myself keeping a running document of what the principles actually were. Definitions of what the principles were supposed to be. Those definitions changed depending on the different cases you may have. Not a lot, but slightly.*

*I kept referring back to those. **By doing that and reading through those definitions and what they mean, it helped me identify either additional stakeholders that maybe I hadn't thought about before, and really try to think of what their perspective might be in the context of the four principles**. It definitely helped from that perspective.*

***Interviewer**: If you can think of one, can you give me an example, maybe from the class? Doesn't have to be.*

***Isabelle**: I'm gonna go back to what I know. When we were doing the case with the bone scanner, looking at autonomy, for example, I found a really good definition of autonomy when it relates to healthcare situations. It was something like, "Autonomy is the patient's ability to make informed, educated, healthcare decisions free from undue outside influence," or something like that was the definition that I had found.*

*You always think about the patient when it comes to healthcare.* ***When I started thinking about that in the context of the case, it made me think that doctors are almost in the same situation as the patient****, in that if the companies are providing them with misleading information or misrepresenting what their products can do, and providing all kind of incentives and things, that can really cloud a doctor's judgment or ability to make the best decision for their patients.*

*What's reinforced to them is there's something called AdvaMed now, which is forcing companies to disclose and track how much money they're spending, and the kinds of promotional ways that they interact with physicians, especially with the higher risk products, specifically to try to curb that undue influence or external influence that can make doctors make decisions more based on profit or the fact that they're getting incentives from these companies. That was really interesting.* ***It all clicked for me on that case, at least with autonomy there****. It made sense to me.*

In this next critical incident, Mark directly references changes in his process of working through the ethics transfer case at the end of the course as compared to the beginning. The second time around, he suggests that he started off by identifying the stakeholders and used the principles to guide him when considering these stakeholders' perspectives. These results do align with the Reflexive Principlism rubric, as this student increased by 4 points out of 10 on the perspective-taking component when comparing his post- and pre- course submissions.

***Interviewer****: First of all, what were your overall impressions of that activity [the ethics transfer case]?*

***Mark****: [Pause] Yeah. I was looking at my answers. When I first did that, it was you're just thinking at it from a, "What's your moral instinct on the case? What's the right course of action for this company engineer to take while he's also serving as a consultant?" My first reaction was, "The EPA, they're just being obstructionists. They're not trying to help the situation by setting standards that nobody can meet."*

*Then after going through the course, you're thinking,* ***"Oh, well, you really have to consider all the stakeholders involved in this case. The EPA is one of them."*** *That was an interesting way to reframe that case, because we were thinking about the company engineer. You're thinking about the people that are gonna use the wood stoves, the people that already do use the wood stoves, but they need to retire the ones they have because they're too polluting.*

*My answers ended up becoming very different, because even though my conclusion* ***about what needed to be done was the same, the way that I came to my final answer was quite different*** *'cause I had to–*

***Interviewer****: The second time you said was different?*

***Mark****: Yeah, when I redid the case after the course. It was I could build my flow chart in a completely different way, because* ***I was considering the stakeholders involved, their perspectives, and then also the four principles****.*

*What I saw actually was the first principle that seemed most important was beneficence, which had never come up in any of the other in-class cases for me, because* ***I saw that this company engineer who was also a consultant had this unique stakeholder position****. Because he was in a position to potentially do a lot of good by engineering a product that was very robust, that could deliver very low pollutants and the emissions of the stove. Then also, consult the EPA on what would be the most beneficial action for all these people who buy the wood stoves to meet standards. He had this interesting position that he could take there to influence a lot of good, that kind of government industry position.*

***Theme B4: Worldview broadening***

This theme suggests that students' broadened their perspectives and worldviews as they began to consider and adopt novel perspectives. While this theme relates to the open-mindedness theme, it is explicitly about integrating or merging another's perspective into one's own. In this initial critical incident, Hoshi discusses how some of the sharing of perspectives throughout the course opened his eyes, and eventually led to changes in his own ways of thinking (note: this incident was presented earlier as part of Theme A1).

***Interviewer****: You mentioned you saw [pause] – I'll just ask, what components of the course, if any, helped you take the perspectives of others?*

***Hoshi****: Listening to the in-class discussion. I really enjoyed hearing what other people's opinions were. The in-class discussions. [Pause] Just listening* *to other people's opinions really opens other people's eyes. Certainly my eyes, for instance, of things I never thought about, or things like that.*

***Interviewer****: Can you provide any specific examples?*

***Hoshi****: Oh, of a time where my opinion was different?*

***Interviewer****: Sure.*

***Hoshi****: Going back to the first case, you're so dead set on I think. I think that you should just help as many people as possible with this one device. I can't remember what it was. Then when you hear some of the arguments on the other side, you get this completely contrasting idea. It starts to build onto you. You might change your mind. That happened to me. That would be an example of just listening to other people's perspectives and opinions gave me new information that* ***made me change the way I thought too****.*

In this next passage, Ling discusses how the broadening of his own perspective was a common recurrence, often happening as a result of the asynchronous online discussion postings. He ends by discussing a specific case study – the Osteopenia case – and how another student discussed a possibility this student had not considered previously, alongside the resulting impact of this divergent perspective on his own worldview.

***Interviewer****: Do you think your group discussions, when you had to maybe complete the case reports or post into Open Class, do you think those discussion were effective for learning the case material?*

*Ling: Yes. The group discussion is slow online, but you do. Yes, it's effective.* ***For most of the cases, our opinions are not very different.*** *In one case, there is some different opinions in the case. We post our different opinions online. After one or two days, we make an agreement. That is very effective, I think.*

***Interviewer****: [Pause] Do you think it was effective for changing your thinking about the issues themselves?*

***Ling****: Yes.* ***For most of the cases, if I have an opinion and another people comment [on] my opinion, and they take their perspective from a broader view, so what other people might think, that there might be some other cases that you didn't consider, and that should also be considered in your opinion****. That's very useful. Because for example, in the case that for the scanning device, that other people might said that there should be another usage of this device in the hospital. Maybe the company can still develop those devices, and the hospital can use it in different ways.* ***I didn't consider that****, and that's very useful for this discussion.*

***Theme B5: Social responsibility realization***

This last theme indicates that as a result of participating in the course, students developed a greater sense of social responsibility. Although this last theme only had one critical incident mapped onto it, it was highly intriguing as it came from one of two participants who were in Mechanical Engineering. Rex describes how the perspective of the professor leading the Kansas City Skywalk case altered his own. The professor described the professional responsibility of engineers in a way that the student described as “enlightening”, where the professor’s description suggested engineers must be held to the highest standard, ensuring their designs are optimally safe to the point where the engineer would even put their life on it.

> ***Interviewer****: Overall, over the course of the semester, has your thinking or understanding of engineering ethics changed in any way?*
>
> ***Rex****: [Pause] No, in terms of the basics. [Pause] Do right by other people. Those things remain consistent. It has changed, I would say. In terms of the one lecture we had in terms of beneficence, having that point of view from I believe the professor was also an ME in that lecture, I forget. Having his point of view as to what it means to be beneficent, and how that plays into being ethical, especially in engineering, was very educational.*
>
> *He was talking about, “Okay, well, the idea behind beneficence is you’re doing active amounts of good in order to hopefully counteract any unintentional maleficent acts that may slip through the cracks.”* ***To be an engineer, you have to be willing to go above and beyond in the sense that you’re willing to fall on your sword. You have to be that beneficent, because there are lives at stake in this field.***
>
> *That is always at the back of my mind as – other engineers, too. I don’t think that idea is so much reinforced in my experience in engineering, the idea of falling on your sword, being the proverbial samurai committing Seppuku. It was good to hear that, because actually, that should be the first thing in engineering 101 that should be emphasized. [Pause]* ***That idea of self-***

***sacrifice should be there in an engineer's mind first and foremost.*** *That was very enlightening to me, anyways*.

**Phase 4.2C: Mapping the critical incidents**

This section explores the cross-categorization of the critical incidents from sections 4.2A and 4.2B. This mapping is depicted first in a matrix format and second graphically. I categorized each critical incident to only one theme pertaining to my interpretation of *causes* of change and one theme pertaining to the *nature* of change research sub-questions. As a result, Table 4.18 situates each incident into the cell that aligns with the two themes it previously fit. As the matrix is 6x5, there are 30 possible relationships. Yet, I only analyzed the 27 captured incidents and therefore not every cell is filled.

The saturation of cells in Table 4.18 (e.g. those with more critical incidents mapped into them) is an indication of the confidence of that finding. In other words, a cell with only one incident mapped into it may be insightful but will require quite a bit of further study, whereas a cell with three or more incidents would contain more than 10% of the themes and would be a much stronger finding. Due to the small sample size (n = 27) and accompanying small number of critical incidents, this mapping is highly preliminary and should be followed up by studies of a more confirmatory nature. Only then might reader consider the findings broadly generalizable.

At the end of this mapping, 17 cells were unfilled, four cells had one incident mapped onto them, five had two incidents mapped onto them, three had three incidents mapped onto them, and the last had four incidents mapped onto it.

**Table 4.18:** *Mapping critical incidents by cause of change and nature of change*

| A. CAUSE OF CHANGE | B. NATURE OF CHANGE | | | | |
|---|---|---|---|---|---|
| | **B1: Open-mindedness** | **B2: Holistic PT** | **B3: Principle-based PT** | **B4: Worldview Broadening** | **B5: Social Responsibility** |
| **A1: Sharing** | **4 incidents** | *1 incident* | - | **3 incidents** | - |
| **A2: Challenge** | **2 incidents** | **2 incidents** | **2 incidents** | - | - |
| **A3: Projection** | **3 incidents** | *1 incident* | - | *1 incident* | - |
| **A4: Emotional** | - | **2 incidents** | - | - | *1 incident* |
| **A5: Repetition** | - | - | **3 incidents** | - | - |
| **A6: Dissonance** | **2 incidents** | - | - | - | - |

Figure 4.4 shows a graphical depiction of these relationships between critical incidents. The dark cells within the middle correspond to the *nature* of change incidents, whereas the unfilled bubbles pertain to the experiences that sparked change. The strength of the connections are represented by the boldness of the adjoining lines, where the 'strongest' linkages are the thickest and the linkages that are barely visible are 'weakest'.

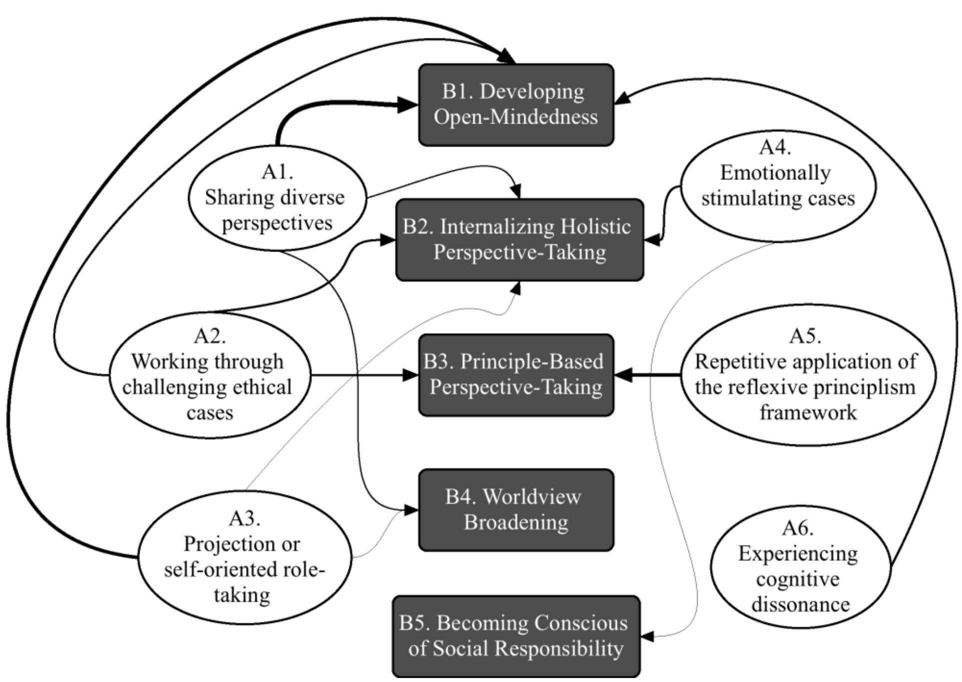


**Figure 4.4**: *Connecting causes of change in perspective-taking with outcomes*

While all of these results are highly preliminary and should be supported by follow-up confirmatory studies, the links that are barely visible should be considered the *most* preliminary and, therefore, in need of the most extensive follow-up investigation.

## PHASE 4.3: COMBINED DATA INTERPRETATION AND DISCUSSION

The objective of this third phase was to integrate results from the previous two phases and use this mixing to further develop the findings from each section in light of one another. With this goal in mind, Phase 4.3 explores the research question, "What insights emerged from integrating the qualitative results regarding students' critical experiences with the quantitative results from the Interpersonal Reactivity Index and Ethics Transfer Case?"

Phase 4.1 showed students had significant increases in their perspective-taking tendencies by comparing pre- and post- course responses to the Perspective-Taking scale of a self-report instrument validated in the field of social psychology called the Interpersonal Reactivity Index (IRI, M. H. Davis, 1980; 1983). Phase 4.1A presented results along other factors of the IRI (including the Fantasy, Empathic Concern, and Personal Distress scales) but did not explore these categories for change through non-parametric testing or t-testing. In Phase 4.1B, results from the newly developed Ethics Transfer Case Methodology (ETC, Hess et al., 2014) showed students had slight increases along the perspective-taking measure, but the pre- and post- comparisons were not significantly different. As with the IRI, the ETC included other categories that I did not explore for change (including Specification, Identification, Reflectivity, and

Justification). Due to the small sample size (n = 19), these quantitative procedures had the limitation of small statistical power.

Phase 4.2 explored critical incidents or experiences that may have sparked the changes found in Phase 4.1 using critical incident technique (CIT). The focus in Phase 4.2 was twofold, firstly exploring what components of an ethics course may have caused changes in students' perspective-taking and secondly exploring what that nature of change appeared to look like. Here, the small sample size limited the generalizability of these findings.

In Phase 4.3, the mixed methodology comes full circle, integrating the findings from these initial two phases. I perform this data integration by considering which experiences (as captured via the critical incidents) seemed to spark the greatest increases along the Perspective-Taking components of the IRI and ETC. This mixing phase lessens the limitations from Phases 4.1 and 4.2 by triangulating the findings from each.

Bryman (2006) describes a series of processes or outcomes used prominently throughout social science research to integrate quantitative and qualitative methods. These include: (a) **triangulation** or "seeking corroboration between quantitative and qualitative data", (b) **complementarity** or seeking "elaboration, enhancement, illustration, clarification of the results from one method with the results from another", (c) **development** or using "results from one method to help develop or inform the other method", (d) **initiation** or "the discovery of paradox and contradiction", and (e) **expansion** or extending "the breadth and range of enquiry by using different methods for different inquiry components" (p. 105).

The integration discussed here achieves a few of these outcomes described by Byrman (2006) with the primary benefit of mixing the data being triangulation, corroboration, and further development of findings. Here the focus was on how impactful specific critical incidents were by examining pre-post changes along the quantitative measures for students who experienced the same critical incidents. In addition, through this integration process, the quantitative results further develop the qualitative and vice versa. Likewise, this process elucidates potential contradictions in the data (e.g. students having critical incidents but not showing changes along the quantitative measures). As a first step in mixing the results, the following section compares qualitative and quantitative data at an individual level to provide a holistic picture of this study's findings.

**Comparing QUAN and QUAL Results at an Individual Level**

As a first step in this mixing phase, I examine quantitative and qualitative results by individual in relation to one another. Table 4.19 maps students' critical incidents alongside their pre-, post-, and difference scores for the IRI and ETC. I do not present difference scores by themselves because, theoretically, if a particular student scored highly on a measure pre-course, their overall increase in the quantitative measures ought to have been less than the increase for another student who scored lower in the quantitative measure pre-course but had the same exact critical experience. For example, if a student scored perfectly on the perspective-taking measures pre-course, they literally could not improve on that measure whatsoever.

The "x" marks within Table 4.19 denote if a student had at least one critical incident mapped according to the corresponding theme. Students may have had two or more critical incidents that corresponded to a single theme, but this was not marked differently. Likewise, as Table 4.19 shows, there were some students who had critical incidents but did not increase along the quantitative measures. Likewise, there were students who did not have critical incidents (per my own interpretation of the interviews) but who did have changes along the quantitative measures. While these contradictions are noteworthy, for the most part, Table 4.19 shows alignment in the results between the quantitative and qualitative portions. For instance, there were only four cases where a student had at least one critical incident depicted but who did not increase along at least one of the quantitative measures (e.g. Ted, Rex, Nicole, Gilia). One of these students, Nicole, actually had the most negative changes across each quantitative measure. The other three students scored above the majority of students on at least one of the pre-course quantitative measures.

**Table 4.19**: *Integrating the qualitative and quantitative results by student*

| | QUALITATIVE RESULTS | | | | | | | | | | | | QUANTITATIVE RESULTS | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *Cause of Change*** | | | | | | *Nature of Change*** | | | | | *Interpersonal Reactivity Index* | | | *Ethics Transfer Case* | | |
| **Pseudonym** | **#*** | **A1** | **A2** | **A3** | **A4** | **A5** | **A6** | **B1** | **B2** | **B3** | **B4** | **B5** | **Pre** | **Post** | **Diff** | **Pre** | **Post** | **Diff** |
| Ashley | 1 | | X | | | | | X | | X | | | 4.00 | 4.00 | 0.00 | 8 | 9 | **1** |
| *Bakari* | *2* | | X | | | | X | X | | | | | *3.71* | *4.57* | ***0.86*** | *6* | *6* | *0* |
| Chi | 3 | | X | X | | | | X | | X | | | 3.71 | 4.00 | **0.29** | 4 | 10 | **6** |
| *Duman* | *1* | | | | | | X | X | | | | | *3.00* | *3.57* | ***0.57*** | *5* | *8* | ***3*** |
| Erica | 0 | | | | | | | | | | | | 2.86 | 3.71 | **0.86** | 3 | 1 | -2 |
| *Fred* | *0* | | | | | | | | | | | | *4.29* | *4.29* | *0.00* | *3* | *7* | ***4*** |
| Gilia | 3 | | X | X | X | | | X | X | | | | 4.14 | 4.00 | -0.14 | 4 | 4 | 0 |
| *Hoshi* | *2* | X | | X | | | | | | | X | | *2.57* | *3.00* | ***0.43*** | *2* | *2* | *0* |
| Isabelle | 3 | | | X | X | X | | | X | X | | | 2.86 | 3.71 | **0.86** | 7 | 6 | -1 |
| *Jia* | *2* | X | | X | | | | X | X | | | | *4.71* | *5.00* | ***0.29*** | *4* | *3* | *-1* |
| Kirian | 2 | X | | | | | | X | | | | | 2.29 | 4.14 | **1.86** | 6 | 8 | **2** |
| *Ling* | *1* | X | | | | | | | | | X | | *2.86* | *3.86* | ***1.00*** | *5* | *7* | ***2*** |
| Mark | 2 | | X | | | X | | | X | X | | | 4.00 | 3.86 | -0.14 | 5 | 9 | **4** |
| *Nicole* | *1* | X | | | | | | X | | | | | *3.29* | *2.57* | *-0.71* | *8* | *4* | *-4* |
| Olive | 1 | X | | | | | | | | | X | | 3.71 | 3.86 | **0.14** | 3 | 6 | **3** |
| *Phoebe* | *0* | | | | | | | | | | | | *3.29* | *4.00* | ***0.71*** | *7* | *6* | *-1* |
| Rex | 1 | | | | X | | | | | | | X | 3.43 | 3.43 | 0.00 | 7 | 3 | -4 |
| *Sammy* | *1* | | | | X | | | | X | | | | *3.86* | *3.43* | *-0.43* | *6* | *8* | ***2*** |
| Ted | 1 | X | | | | | | X | | | | | 4.86 | 4.57 | -0.29 | 9 | 8 | -1 |

[*]The number sign (#) refers to the number of critical incidents the student experienced in total. It was possible for a student have multiple critical incidents mapped to a single theme, so a "3" would not require 3 "x" marks pertaining to one of the qualitative research foci.
[**]The "x" marks denote that the student had at least one critical incident mapped to the corresponding theme.

### Comparison by Gender

An initial surprising insight derived through examination of Table 4.19 (especially Nicole's large decrease) was female students tended to improve less than males, not only having fewer critical incidents depicted through the interview process on average, but also having lower difference scores along the IRI and ETC. This insight led to a direct comparison of scores by gender, as shown in Table 4.20. This 'eye-ball' test was not unfounded, for females' increases along the IRI was nearly a third of males'. Females also had slightly fewer critical incidents derived from the analysis. Furthermore, the female participants, on average, *decreased* on the ETC. Only 3 of the 8 female participants saw increases in the ETC Perspective-Taking measures (Olive with a three point increase, Sammy with a two point increase, and Ashley with a one point increase). As a result, the female participants' post-course scores were nearly 10% below males'.

**Table 4.20**: *Comparing 'mixed' results from CIT, IRI, and ETC by gender*

| | Sample | Critical Incidents | | IRI | | | ETC | |
|---|---|---|---|---|---|---|---|---|
| | *N* | *Average* | *Pre* | *Post* | Δ | *Pre* | *Post* | Δ |
| **Females** | 8 | 1.25 | 3.5 | 3.66 | 0.16 | 5.75 | 5.50 | -0.25 |
| **Males** | 11 | 1.55 | 3.58 | 4.03 | 0.44 | 5.09 | 6.45 | 1.36 |

The question then is, what happened? Why were female students' changes and final scores largely distinct from their male colleagues? As all three sets of data support the finding that males had more positive increases in perspective-taking than did females, perhaps there was some component of the course itself that was more impactful for male students.

The overall ratio of male to female participants was slightly leaning towards males, which meant that in all but one of the groups there were more males than females (Group 4 was a 50/50 split). Perhaps out-of-class group meetings led to unique experiences by gender. Group norms may dictate how students within teams interact with one another. Generally, if group norms are focused on cooperation or interdependence then “members are likely to develop shared views about ways to approach and accomplish their required tasks” (Chatman & Flynn, 2001, p. 960). While groups that are too heterogeneous may not reach this level of “shared views”, if there is “proper management of diversity” (McLeod, Lobel, & Cox, 1996) or the group norms emphasize cooperation (Chatman & Flynn, 2001) group tensions should be minimal.

As instructors were not present when groups worked through their reports, we could not ascertain if there existed varying levels of group tensions. It is possible that group norms embedded within the broader engineering culture may have impacted group norms and, in turn, individual group members course experiences. As described in Chapter 3, Foor, Walden, Shehab, and Trytten (2013) found female engineering students may face unique stereotyped gender roles and work schemas within group settings as a result of broader cultural factors and norms. While one of the female students in their study persisted amidst such stereotyping partly due to a supportive group structure, another altogether left engineering.

An alternative explanation may take into account the effect of each of the leading professorate being male. As a result, perhaps due to the lack of female instructors, female students felt less engaged with the course content and thereby had less “critical” experiences. Role modeling has been considered important for improving female engineering students' retention (Felder et al., 1995) and self-efficacy (Yasar et al., 2007). It has been shown that personal interactions with same-sex experts (namely, female engineers or instructors) can improve a female students' self-concept, self-efficacy, and implicit identification with engineering *although* this does not tend to reduce participants' perceived gender stereotypes (Stout, Dasgupta, Hunsinger, & McManus, 2011). This might indicate that the lack of female instructors in the ethics course may have reduced the profoundness of female participants' experiences (particularly, their number of critical experiences) within the course as a result of their (potentially lacking) self-identification with the course content. Each of these interpretations are speculative and our research team will explore and refine these speculations as additional students participate in the course and we gather additional data in the future.

**Comparison by Race**

Following gender comparisons, I compared the data by race. Results from non-White students were compared with White students, for if the gender differences were related to the fact that leading professorate were not female, perhaps the same issue would have occurred with non-White students, as every course professorate was White. Yet, as Table 4.21 shows, exactly the opposite was true. The non-White students, half of whom were international students, saw changes along the IRI that were more than six times higher than the White students, on average. At the end of the courses, these students' perspective-taking scores along the IRI (at 4.02) were well above the averages reported for engineering students in other studies (e.g. in Hess et al. 2015 $\mu_{PT,IRI} = 3.65$; in Rasoal, Danielsson, & Jungert, 2012 $\mu_{PT,IRI} = 3.57$).

Nonetheless, while non-White students' difference scores along the ETC were more than 15 times higher than White students' difference scores, at the end of the course scores across the two groups along the ETC were almost identical. As with the gender comparisons, I sought to corroborate these findings with the qualitative results, where non-White students had twice as many critical incidents when compared to White students (see Table 4.21).

**Table 4.21**: *Comparing 'mixed' results from CIT, IRI, and ETC by race*

| | Sample | Critical Incidents | IRI | | | ETC | | |
|---|---|---|---|---|---|---|---|---|
| | *N* | *Average* | *Pre* | *Post* | Δ | *Pre* | *Post* | Δ |
| **White** | 11 | 1 | 3.68 | 3.77 | 0.09 | 6.00 | 6.09 | 0.09 |
| **Non-White** | 8 | 2 | 3.38 | 4.02 | 0.64 | 4.50 | 6.00 | 1.50 |

Again, the pertinent question is, what happened? Why did the non-White students appear to have such a significantly different experience when compared to their White colleagues? Part of an explanation for this finding may within emerging cultures ethical cases are rarely discussed. A separate indication might be that international students are actively experiencing a new culture, perhaps even cultural shock, where the majority of standards of social intercourse are entirely novel (Oberg, 1960). As a result, these students may have grasped the value of perspective-taking at a level unique from domestic students. For example, "cultural empathy" is essential for intercultural competence, which is particularly important when one enters a new cultural environment (Cui & van den Berg, 1991; Kim, 1988). Winkelman (1994) discusses techniques for successful "cross-cultural adaptation" that involve "integrating one's original identity with a new identity created in the new culture" (p. 124). Winkleman explains this includes not only empathy, but also much more:

> *Personal changes can be achieved by cognitive flexibility (openness to new ideas, beliefs, and experiences and the ability to accept these new conditions) and behavioral flexibility (the ability to change behavior as required by the culture). Emotional changes require more than knowledge, empathy, and understanding. One needs to simulate new behaviors and to express affective aspects (emotions, feelings) expected in the culture. (p. 124)*

**Comparison by Gender/Race**

As a third mixing step, I compared results across sections by race and gender (see Table 4.22). Due to the very small sample sizes, these findings are highly preliminary. The trends indicated that Gilia, the single non-White female student, had reported the most critical experiences. Yet, Gilia left the course with a still high although slightly decreased perspective-taking score from the IRI and a below average score to the ETC. Non-White male students, in contrast, scored well above average along the ETC at the end of the course, and increased significantly along the IRI measure. Indeed, before the course these students' responses to the IRI were well *below* averages reported for engineering students in other studies (e.g. Hess et al., 2015; Rasoal, Danielsson & Jungert, 2012) but well *above* these same averages post-course. Along the IRI, Gilia started high and ended high.

**Table 4.22**: *Comparing 'mixed' results from CIT, IRI, and ETC by race and gender*

| | Sample | Critical Incidents | IRI | | | ETC | | |
|---|---|---|---|---|---|---|---|---|
| | *N* | *Average* | *Pre* | *Post* | Δ | *Pre* | *Post* | Δ |
| **White, male** | 4 | 1.0 | 4.14 | 4.04 | -0.11 | 6 | 6.75 | 0.75 |
| **White, female** | 7 | 1.0 | 3.41 | 3.61 | 0.20 | 6 | 5.71 | -0.29 |
| **non-White, male** | 7 | 1.86 | 3.27 | 4.04 | 0.76 | 4.57 | 6.29 | 1.71 |
| **non-White, female** | 1 | 3.0 | 4.14 | 4.00 | -0.14 | 4 | 4 | 0 |

Part of the explanation of these results may involve an intersection of the *role modeling* and *cultural adaptation* effects previously described. As a minority across the race, gender, *and* disciplinary dimensions, Gilia may have faced particularly unique challenges not systematically captured in our sampling strategies. Gilia was the single African student in the course and had a Mechanical Engineering background. Despite the results shown, Gilia self-reported having an "increase" in perspective-taking, and opened up the interview discussing favorability towards the perspective-taking components of the reflexive principlism framework. Gilia reported feeling comfortable sharing her perspectives within her group, although throughout the interview she did not talk much about group tensions. While prior research has indicated that the experiences of female students, particularly female students who are ethnic minorities, may be particularly challenging due to dominant images and associated norms within and beyond the class experience (Foor et al. 2013; Foor, Walden, & Trytten, 2007), Gilia seemed to indicate that the perspective-taking activities mitigated these negative effects.

**Comparison by Critical Experiences**

An alternative method for approaching curricular experiences is to explore how the incidents mapped according to the critical incident as grouped by race and gender.

For example, were there any experiences females had which males did not? What does a comparison of experiences between White students and non-White students elucidate?

A comparison by race shows that four non-White students reported **self-oriented perspective-taking** as a critical incident compared to only one white student. In contrast, three White students reported having **emotionally powerful** experiences as compared to one non-White student. Lastly, two White students reported **repetitive application of principles** as a critical experience compared to zero non-White students, whereas two non-White students (both of whom were international students) reported experiencing **cognitive dissonance**.

There were fewer distinctions by gender. The two main differences were along **emotionally powerful** experiences, grouped to three females as compared to one male. Additionally, two males reported experiencing **cognitive dissonance** compared to zero females. Based off these considerations, the following section compares the impact of specific critical experiences on perspective-taking changes.

**Causes of change from CIT compared along IRI and ETC**

This section explores pre-post changes along the quantitative measures in relation to students who reported experiencing the same critical incidents. In Table 4.23, the number of students who had a specific critical experience was presented, where the IRI and ETC measures reported are the averages taken solely from those students who experienced that incident (as elucidated by my interpretations from the qualitative analysis).

**Table 4.23**: *Descriptive statistics grouped by critical incidents along cause of change*

| | Students | Interpersonal Reactivity Index | | | Ethics Transfer Case | | |
|---|---|---|---|---|---|---|---|
| | *N* | *Pre* | *Post* | *Diff* | *Pre* | *Post* | *Diff* |
| A1: Sharing | 7 | 3.47 | 3.86 | 0.39 | 5.29 | 5.43 | 0.14 |
| A2: Challenge | 5 | 3.91 | 4.09 | 0.17 | 5.40 | 7.60 | **2.20** |
| A3: Role-taking | 5 | 3.60 | 3.94 | 0.34 | 4.20 | 5.00 | 0.80 |
| A4: Emotion | 3 | 3.62 | 3.71 | 0.10 | 5.67 | 6.00 | 0.33 |
| A5: Repetitive | 2 | 3.43 | 3.79 | 0.36 | 6.00 | 7.50 | 1.50 |
| A6: Dissonance | 2 | 3.36 | 4.07 | **0.71** | 5.50 | 7.00 | 1.50 |

On average, students who experienced any of the critical incidents had increases in perspective-taking tendencies as measured by the IRI and ETC. This suggests that *each* of these critical incidents were influential for changing students' perspective-taking tendencies to some extent. However, as the quantitative data shows in Table 4.23, it also suggests that some incidents may be more critical in terms of increasing perspective-taking tendencies.

**Sharing of diverse perspectives** was the most pervasively coded critical incident, and it aligned with a moderate increase in perspective-taking as measured by the IRI. However, students who had this experience showed only slight improvements on the ETC. These students scored 5.4/10 on the post-course transfer case, which may be an indication that the transfer case, as an individual activity, is not directly measuring this interpersonal, collaborative theme.

In contrast, students who recognized the **challenge** of ethical decision-making as being influential in their perspective-taking changes saw the greatest increases along the ETC. While these participants' IRI increases were minimal, on average, these students scored the highest along the ETC *and* IRI post-course. This suggests that it is important to enable students to recognize the 'wickedness' (Seager, Selinger, & Wiek, 2012) of ethical problems alongside providing students with an approach to work through the wicked aspects of these problems.

**Self-oriented** perspective-taking activities were related to moderate increases along both the ETC and IRI. Interestingly, however, the ETC results showed students only scored 5/10 on the ETC post-course. This may be an indication that self-oriented perspective-taking is insufficient to score well on the ETC, as perhaps these students honed in on a single stakeholder (e.g. the engineer who works for the wood stoves company and consults the EPA) as opposed to providing a holistic depiction of all stakeholders involved in the case. In other words, to score well on the Perspective-Taking scale of the ETC one must consider a broad range of stakeholders' perspectives, as opposed to intimately exploring a single stakeholder's perspective.

Overall, **emotionally powerful** critical incidents contributed the lowest to changes in perspective-taking. This supports M. H. Davis's (1983) notion that emotional concern and perspective-taking are not the same thing, although they may be slightly related. Further, this supports the notion from Hoffman (2000) who suggested that too much emotive content would be detrimental to perspective-taking. A review of the critical incidents within this category indicate that students tended to focus solely on a single stakeholder, although it was not clear if students experienced 'over-arousal' as described by Hoffman. This is a potential indication as to why female students' perspective-taking changes were of lower magnitude than males'.

**Repetitive** application of the reflexive principlism approach was theoretically something every student experienced. The two students who verbalized this critical incident may be students who were the most meta-cognizant of the role of the principles in changing their perspective-taking tendencies in a real-world context. These students saw a significant increase in their scores on the ETC and a moderate increase in perspective-taking as measured by the IRI. On average, these respondents scored 7.5/10 on the ETC post-course. This complements the findings between the two measures, as this theme suggests students transferred the use of the reflexive principlism approach outside of the course, which is what the ETC was designed to measure (hence the phrasing "Ethics *Transfer* Case").

Students who experienced **cognitive dissonance** scored second highest post-course along the IRI. Furthermore, these students saw the greatest increase in perspective-taking as measured using the IRI, and they also significantly improved on the perspective-taking category of the ETC. This is a potential indication as to why non-White students saw the greatest gains in perspective-taking tendencies. It also suggests that students who experience dissonance and avoid becoming over-distressed will have the most profound experiences in an ethics course where they encounter particularly unique perspectives. *Cultural adaption* strategies for immersing one's self within a new culture may explain part of this theme.

**Nature of change from CIT compared along IRI and ETC**

This section applies the same analysis process as in the previous section, but here the focus was on how critical incidents pertaining to the *nature* of change research question aligned with the quantitative results. Table 4.24 shows an overview of this comparison.

**Table 4.24**: *Descriptive statistics grouped by critical incidents along nature of change*

| | Sample | Interpersonal Reactivity Index | | | Ethics Transfer Case | | |
|---|---|---|---|---|---|---|---|
| | *N* | *Pre* | *Post* | *Diff* | *Pre* | *Post* | *Diff* |
| B1: Open-mind | 9 | 3.75 | 4.05 | 0.30 | 6.00 | 6.67 | 0.67 |
| B2: Holistic | 5 | 3.91 | 4.00 | 0.09 | 5.20 | 6.00 | 0.80 |
| B3: Principles | 4 | 3.64 | 3.89 | 0.25 | 6.00 | 8.50 | 2.50 |
| B4: Worldview | 3 | 3.05 | 3.57 | 0.52 | 3.33 | 5.00 | 1.67 |
| B5: Social Resp. | 1 | 3.43 | 3.43 | 0.00 | 7.00 | 3.00 | -4.00 |

As Table 4.24 shows, on average, students who had critical experiences pertaining to any of these themes saw benefits in the IRI and ETC results, with the one exception being the **social responsibility** category. In fact, the single student who had this critical experience saw no changes in the IRI measure and a significant decrease in score along the ETC. This is likely an indication that the social responsibility theme does not capture "empathic perspective-taking" as measured by the IRI and ETC, although, this will need to be explored in the future as the sample size increases.

The **open-mindedness** theme was by far the most pervasive. The nine students who had critical incents mapped to this theme had moderate increases both along the IRI and ETC. These nine students showed IRI scores of 4.05/5 at the end of the course, which was the highest of all averages in Table 4.24. This finding resonates with the correlations between the "cultural empathy" and "open-mindedness" scales of the Multicultural Personality Questionnaire as reported by van Oudenhoven, Mol, and Van der Zee (2003). These authors defined open-mindedness as "an open and unprejudiced attitude towards outgroup members and towards different cultural norms and values" (p. 160f) and of their

10 survey measures, the correlation between cultural empathy and open-mindedness was the highest.

The five students who had critical incidents mapped to the **holistic perspective-taking** category saw moderate increases along the ETC and slight increases along the IRI. These students scored just lower along the IRI, at 4.00/5. While these students did increase by nearly a point between pre- and post- course along the ETC, their final scores were 6/10 which is slightly lower than what I expected given my interpretation of this theme.

The four students who shared incidents which suggested they were more likely to use **principles** to guide their perspective-taking not only had the greatest changes along the ETC, they scored well above the post-course participant average (8.50 compared to 6.05). This directly corroborates the findings from the quantitative and qualitative phases. Perhaps in future course offerings, direct instruction on using the principles as a tool for perspective-taking is needed. On the other hand, as Figure 4.4 shows, perhaps working through more cases would lead more students to transfer usage of the reflexive principlism approach outside of the course.

Lastly, the three students who had experiences mapped to the **worldview broadening** theme saw the largest increase along the IRI results along with a moderate increase in the ETC results. While these changes were positive, each of the post-course quantitative measures were still below average for these participants. These findings may indicate that while these students did have a broadened perspective, this theme does not directly correspond to changes in perspective-*taking*. It may be more accurately described as perspectives-*took*.

## CLOSING DISCUSSION

Perspective-taking is a core component of the ethical reasoning approach, reflexive principlism. In order to successfully apply the approach when making ethical decisions within a classroom or in the real-world, decision-makers must have a tendency to *do* perspective-taking. Yet, as Chapter 3 of this dissertation showed, the extent to which perspective-taking (as a component of empathy) is learnable is wholly uncertain. Further, the majority of engineering alumnae in Chapter 3 considered the extent to which they ‘became’ more empathic or caring within undergraduate engineering was minimal or even detrimental. Given the rapid rise of engineering ethics education, and numerous calls for change throughout engineering, educators need methods for developing engineering students’ empathic perspective-taking tendencies.

This study has shown that a multi-disciplinary course on engineering ethics can strongly influence students’ perspective-taking tendencies. It depicted pathways that were most critical in sparking these changes and integrated findings from qualitative and quantitative components to explore any potential contradictions. This mixing elucidated that some experiences were most critical for this study’s participants. Due to the range of experiences highlighted, these findings also indicated there are distinct pathways for the development of empathic perspective-taking tendencies. As the most pertinent *cause* of change was **sharing diverse perspectives**, this indicates educators trying to encourage perspective-taking might accomplish this through a series of steps: (a) gather a diversity of viewpoints for discussion, (b) develop a safe-environment for discussion, and (c) use engaging and challenging problems or cases to spark discussion. These steps could take place within a design project, a wicked problems course, a course on engineering worldviews or identity, or even within a technical course where problem topics or projects are ill-structured.

Differences by gender indicated that female participants had less significant changes than males. Perhaps this is because female students did not establish "role-modeling" relationships due to all faculty being male, or perhaps there were inhibiting group norms for perspective-taking development due to more males than females participating in the course. Yet, differences by race were just the opposite, showing that non-White students had drastically larger changes in perspective-taking than males. Part of an explanation for this may be that non-White students found themselves immersed within a new culture, and perspective-taking was an adaptive technique they internalized to alleviate tensions resulting from their development of a new identity within this novel cultural context. My interpretation of these findings are preliminary and in need of rigorous follow-up studies of a more confirmatory nature.

The two students who experienced **cognitive dissonance** partly explains the drastic differences found by White versus non-White students. This critical incident aligned with the highest changes in perspective-taking as measured using the IRI. This may indicate that situating students into an environment or context where they become particularly 'surprised' by other peoples' perspectives, but *not* overwhelmed or over-distressed, is key for realizing drastic developments in perspective-taking tendencies. In contrast, the critical incidents related to **emotionally powerful experiences** did not correspond directly with changes in perspective-taking, and perhaps this was because these students became over-distressed, which theoretically inhibits empathy from functioning. Given that female students were more likely to report having this experience, this may be an alternative explanation for the differences in perspective-taking changes found by gender.

There is also something to important about repetition of the reflexive principlism process. The old adage, 'practice makes perfect' may ring true here. **Repetitively** applying the reflexive principlism approach to multiple case studies, particularly those that students considered **challenging**, may lead students to become better at applying this approach – including but not limited to the perspective-taking component. Furthermore, as was evident by the range of cases depicted in the critical incidents, students seemed to find unique benefits or take-a-ways from distinct cases. Therefore, not just any case study will do, but rather embedding multiple engaging, diverse, and challenging cases seems especially important, along with giving students the opportunity to balance their perspectives off their colleagues who do the same in turn. Given the **emotional** implications, perhaps cases that are overly emotionally engaging are not ideal, but it would seem that students need some level of emotional engagement to capture their ethical imaginations.

On a related parting-note, empathic distress may be essential to empathic responding, but too much distress may lead to over-distress. Interestingly, although changes in the Personal Distress scale of the IRI were not the focus of this study, nearly every student decreased along this scale, indicating that after the course students were less inclined to feel anxious when encountering tense situation. Perhaps providing students with a systematic approach for working through ethical issues gives students the tools they need to avoid becoming tense, holistically reflect in situ on a dilemma, and maintain the cognitive functioning necessary to consider the relevant perspectives of stakeholders involved in a case. As with all other findings in this study, this too must be explored in the future.

## LIMITATIONS

Due to the limited sample size (n=19) and considering the participants in this study were all graduate students at one university, the quantitative findings were limited by small statistical power whereas the qualitative findings have limited generalizability. Replicating these findings at another university using the same pedagogical framework would significantly bolster the generalizability. Nonetheless, this study is significant insofar as the results generated from this study provide grounding for future work regarding the relationship between engineering, empathic perspective-taking, and moral reasoning and may help other educators striving to teach related concepts.

In terms of exhaustiveness of the qualitative analysis conducted herein, it is possible that new categories would continue to emerge or the existing categories would be refined with more interviews. Due to the limited sample size, this limitation can be alleviated by analysis of interviews conducted with students who participated in course offerings using a related pedagogical framework or course content, and by deductive application of this existing thematic structure. This further inquiry will be a central component of the Cultivating Cultures in Ethical STEM grant application, if funded, that the EESE research team (led by Dr. Brightman as the P.I.) had applied for at the time of this writing.

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CHAPTER V

A SUMMATIVE OVERVIEW:

IMPLICATIONS AND FUTURE RESEARCH DIRECTIONS

# CHAPTER V. A SUMMATIVE OVERVIEW

This final chapter integrates findings from each preceding chapter in order to address the overall research objectives. Furthermore, this chapter provides a summary of the implications of this work, alongside directions for future investigation. Throughout this dissertation, the guiding research objectives included:

1. To develop a conceptual understanding of empathy within engineering
2. To explore the perceived importance and value of empathy within the practice of engineering
3. To understand mechanisms by which engineering students may become more empathic

Chapters 2 and 3 were primarily exploratory, analyzing perspectives from engineering faculty and practicing engineers. These chapters addressed research objectives 1 and 2. In contrast, Chapter 4 was experimental, exploring research objective 3 and focusing on a specific empathic tendency: perspective-taking. Chapter 4 was a direct extension of Chapters 2 and 3, where participants described the "learnability" of empathy and care as uncertain. Furthermore, faculty participants indicated that empathy ought to be embedded indirectly into engineering curriculum. With this in mind, Chapter 4 explored the development of students' empathic perspective-taking tendencies as a result of an educational intervention (students participated in an engineering ethics course). The findings from this mixed methods study were promising, suggesting which categorizations of critical incidents seemed to spark increases in students' perspective-taking tendencies. These critical incidents corroborated Zoltowski, Oakes, and Cardella's (2012) finding regarding the impact of critical experiences in enabling students to reach the highest stages of human-centered design (note that their study was situated within an entirely different context: a service-learning course).

While components of Chapters 2 and 3 explored what empathy and care look like within an engineering context and how empathy and care were most important to engineering practice, themes generated from these chapters did not largely inform how empathy was developed or enculturated. In contrast, Chapter 4 explored a strategy for embedding empathy within engineering curriculum and developmental implications for post-secondary engineering education. Chapter 4 was designed to primarily focus on one component of empathy, empathic perspective-taking, as Hess et al. (under review) theorized that this 'other-oriented' and 'cognitive' form of empathy was the most essential (albeit insufficient in of itself) for ethical decision-making within an engineering context. Nonetheless, as the empathic taxonomy in Chapter 4 and M. H. Davis's (1996) functional model of empathy showed, perspective-taking is only one component of empathy. Although it has been claimed to be the most 'advanced cognitive' form of empathy (Hoffman, 2000), its accuracy is contingent upon the effective functioning of more automated, non-cognitive constituents (de Waal, 2009) and other antecedent capacities (Davis, 1996).

The findings from each chapter are integrated in the following sections, where the foci includes (a) **framing** or conceptualizing empathy within an engineering context, (b) exploring the relation of empathy to engineering **outcomes**, (c) an overview of organizational **contextual** considerations for valuing empathy within industry or across educational institutions, (d) describing how empathy may function towards a broad **range** of stakeholders, (e) the necessity of alleviating empathic **biases** if empathy is to fully perform its epistemic functions within engineering, (f) considering how best to **develop** empathy within engineering curriculum, (g) **implications** of the development of empathic engineers throughout engineering, and (h) **future research** stemming from the work reported herein.

**Framing: Conceptualizing empathy within an engineering context**

One key finding from Chapter 2 was that empathy and care may look different when situated in engineering as compared to traditional contexts, such as nursing or counseling. Theoretically, empathy within engineering might closely align with empathy as described in human-centered or empathic design literature. Yet, while empathic design as a methodology has developed within scholarly literature over the past 20 years, the focus throughout this literature has seldom been directly on engineering. Design is a key component of engineering, but it is one component among several (de Figueiredo, 2008). Therefore, while empathic design literature might inform how empathy may operate within engineering, it does not tell the whole story. This is evident if we compare the focus throughout empathic design literature, which tends to be on product development (e.g. see Leonard & Rayport, 1997; Postma et al., 2012), with the results generated from

Chapters 2 and 3, which include this emphasis but also much more. For example, in Phase 2.3, engineers' open responses suggested that engineering was normatively holistic, or inherently empathic and caring; in Phase 2.2, the faculty participants corroborated this finding, indicating that empathy and care may serve as the driving motivation for engaging in many engineering projects; likewise, in Phase 2.1 the extensive literature review found that 'empathic' or 'caring' engineering projects may be motivated by considerations that are (a) humanitarian, (b) safety-focused, (c) community-oriented, or (d) compassion-related.

Chapter 3 verified much of these findings, as well as further elucidated nuances in engineers' conceptualizations of empathy: the conceptual themes generated from the analysis in Phase 3.1 showed that practicing engineers were, to some extent, aware of empathy's conceptual nuances as defined in contexts where explicit use of empathy is already pervasive. For example, participants spoke to cognitive, emotive, and experiential aspects of empathy emphasized by Batson (2009). Participants also indicated that within engineering, empathy may involve an awareness of the broader context and how elements or multiple stakeholders with that context fit together. This nuance was not described whatsoever in Batson's (2009) overview of the phenomenon (which appears to be a synthesis of literature spanning across the fields of philosophy, cognitive science, neurophysiology, primatology, and developmental psychology) or Kunyk and Olson's (2001) concept clarification of empathy throughout nursing literature.

Participants most prominently describe care as an extension of empathy, acting in some manner, perhaps altruistically due to an empathic, other-oriented understanding. In addition, engineers' conceptions of care included the empathic concern element described by M.H. Davis (1983). Lastly, participants spoke of existing 'standards of care' or 'professional duties'. Taken together, these results led to the framing of a paired empathy *and* care construct. The primary distinction between the phenomena seemed to be that care entails action whereas empathy does not. As a result, participants tended to depict empathy as a more neutral phenomenon than care. The paired empathy/care construct included the development of other-centric understanding and acting upon this understanding with the intention of helping another.

The phenomenological results from Chapter 3 indicated that engineers perceived empathy and care as core and even necessary to their engineering practice. The most prominent theme revolved around ensuring engineering outcomes effectively met users' needs. Furthermore, empathic engineering outcomes were not considered as being only sufficient once delivered to a user or users, but also *optimal*. This optimal theme indicated that empathic engineering outcomes had a direct focus on such factors as safety and efficiency. Optimal solutions may also embed sustainability considerations, generally going beyond existing minimum standards. In this sense, engineering participants were purporting that empathy and care play a key role in motivating practices which are environmentally savvy and socially just, although rarely did participants explicitly use this terminology.

Another key finding from Chapters 2 and 3 was on the role of empathy in developing interpersonal relationships both internally (e.g. amongst team members, with employees) and externally (e.g. with a customer or client). Scholarly literature commonly utilized like-terms such as 'building trust' and 'solidarity' (see Phase 2.1). This nomenclature permeated the discourse in the subsequent thematic analyses.

Participants generally portrayed empathy by what it *does* as oppose to how it *functions*, conceptualizing the phenomenon by grounding it in tangible, and real-world experiences. Participants generally discussed empathy's potentially utilitarian advantages, such as producing economic gains or developing products more effectively. To the extent participants perceived empathy (and care) as detracting from a 'competitive edge', then they considered these phenomena to be of lesser relevance. Participants tended to describe empathy according to its epistemic outcomes, explaining what it generates in terms of other-centric knowledge, and pragmatically, in relation to what outcomes it helps develop (although the 'action' itself was closer aligned with the care-concept). These empathic engineering 'outcomes' are further explored in the following sections.

**Outcomes: The potential results of an empathic engineering process**

Figure 5.1 shows an integrated mapping of the themes generated throughout this dissertation. Since the participants mostly discussed empathic outcomes (e.g. what do empathy and care do?) as opposed to functional considerations (e.g. how do empathy or care operate?) or developmental considerations (e.g. how is empathy or care taught or internalized?), the themes begin with what empathy generates in terms of other-oriented understanding.

The engineering participants' "utilitarian perspectives" led to the generation of a series of higher-level categories in Chapter 3. These outcome-centric categories included

(a) empathic outcomes, (b) relational outcomes, and (c) engineering outcomes. The inter-relationship of these categories, along with the themes they contain, is depicted in Figure 5.1. In other words, Figure 5.1 presents an overview of potential engineering outcomes generated when empathy and care guide the engineering process.

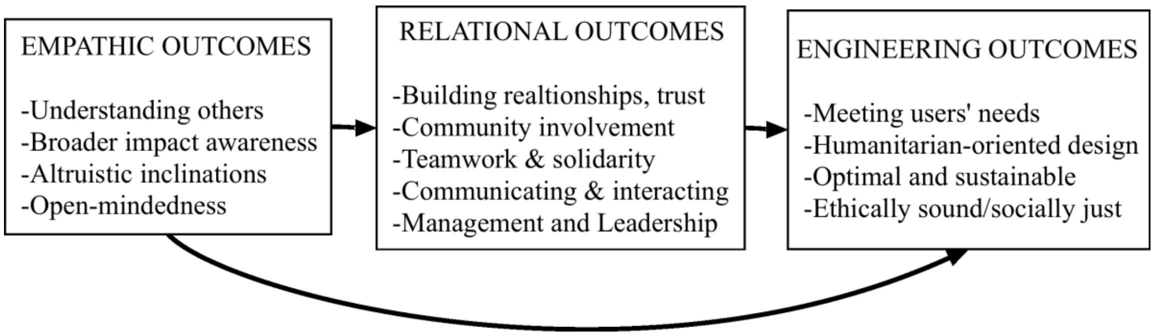


**Figure 5.1:** *Engineering outcomes when guided by empathy and care*

As Figure 5.1 indicates, empathic outcomes play a direct functional role in a specific subset of these engineering outcomes both *directly* and *indirectly*. The indirect route is by generating relational outcomes which then lead to engineering outcomes. Figure 5.1 does not specify whom the engineer is empathizing with, but as the themes in Chapters 2 and 3 highlighted, empathy may be directed from the engineer to the user(s), the engineer towards a colleague, or the engineer and a broader context (including the stakeholders within that context). Furthermore, the framing of the categories and themes depicted in Figure 5.1 is at the level of the individual engineer, an engineering team, or organization. For example, an empathic engineer who understands others and is aware of the broader impact of their decisions may build trust with customers and colleagues, thereby effectively meeting their needs.

As the conceptual findings in Chapter 3 indicated, empathy alone may be insufficient for generating a tangible outcome, requiring a *caring* disposition or action to see the 'empathic engineering outcomes' to fruition. In other words, a feeling of care or empathic concern oriented from the engineer towards a target seems to be necessary for any inter-relationship between outcomes or themes to manifest pragmatically. I have not described inter-relationships at the theme level, as this is a component for future research. As an example, path analysis might elucidate which 'engineering outcome' is best supported by an 'open-minded' individual, and whether this path is mediated by one or more 'relational outcomes' (e.g. teamwork & solidarity, community involvement).

**Context: Organizational culture drives practice**

As one of the themes in Chapter 3 described, empathy and care may only flourish within an organization if leadership promotes empathy and care from the top-down. These findings corroborate the assertion by Sanders (2009) whose focus was on the incorporation of 'co-design' principles throughout organizations. As Sanders describes, an individual within an organization will only adopt co-design tools, methods, and methodologies by if these align with the mindsets and culture of the organization. Figure 5.2 provides a slight adaptation of a graphic depicted within Sanders' paper (I received permission to use this figure from both Dr. Sanders and the editor of the TU Delft Proceedings, Dr. Stappers). In Figure 5.2, 'culture' forms the foundation upon which all other components are built. Similar to Sanders, participants in Chapter 3 suggested that within engineering organizations, if empathy-related phenomena are not core to the organizational culture, they will not gain traction at the individual level.

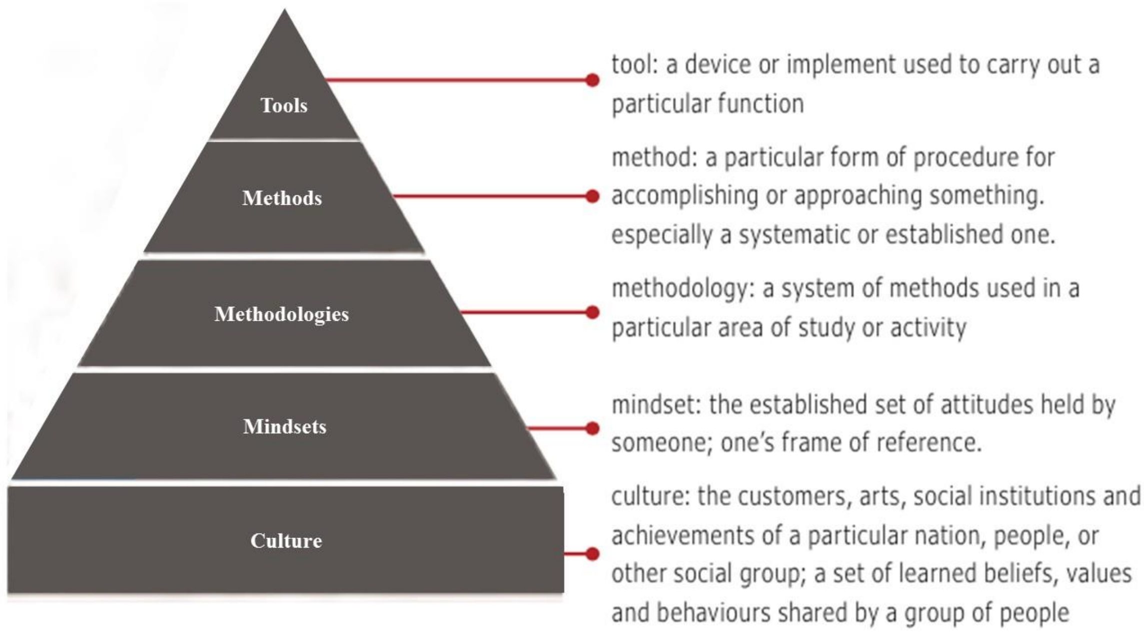


**Figure 5.2**: *Organizational hierarchy for action (adapted from Sanders 2009, p. 24)*

As an engineering faculty member in Chapter 2 described, embedding empathy within engineering education may be difficult. In his experience, he considered "empathy" to be a non-priority for his colleagues. When asked, "Why?" the participant stated, "Oh, because, you know, most of them are guys and most of them are engineers and it's not part of the engineering culture." Yet, a participant in Chapter 3 suggested that the 'undervaluing' of empathy was a product of empathy simply not being on any of his colleagues' radars. Half of his colleagues, he suggested, were 'a-empathic' as opposed to 'un-empathic', being so wrapped up in the technical details of their work, they seldom stepped-back to appreciate the broader or social impact of their work. This appeared to be the case in the interviews with engineering faculty, as many of these participants negated the importance of empathy at the beginning of interviews, then through reflection and discourse, they began to see its utility and even centrality to engineering practice.

In terms of changing the engineering culture, reframing the goals and values of individual higher education systems may be a key place to start. Engineering institutions seeking to embed empathy at an individual level must first reshape their core values towards a greater inclusion of empathy and care in order for these values to become broadly realized at the level of engineering faculty members. The impact of these “empathic” cultures or institutions in comparison to “traditional” or “un-empathic” cultures may be a fruitful area for further investigation. For example, findings from Chapter 2 indicated that a more empathic faculty-base may be an ideal means of gathering and retaining student diversity in the engineering student population.

Kim & Mauborgne (2005) indicated there exist four key hurdles to systemic organizational change: (a) cognitive, or helping individuals see the need for change, (b) limited resources, or perceived risk associated with change, (c) intrinsic motivation, or individuals *wanting* to see change become a reality, and (d) politics, or opposition from long-held interests of key personnel. Their key suggestion was to develop a tipping point by focusing on “kingpins” and gathering a critical mass of individuals with a vested interest in the direction of change. To achieve this, the change agent’s objective becomes to lead people to experience realities that make change necessary, seek out hot spots or the areas where shifting a few resources will spark a lot of change, and appoint a ‘consigliere’ or an insider who knows who is for and who is against change.

In the context of engineering education, if the goal is to motivate institutional professorate to act more empathically, a focus on “kingpins” may involve shining a spotlight on empathic actions of faculty by rewarding such behavior and highlighting the impact of their actions. Another strategy may be to situate professors in courses or contexts where a lack of empathy is evident (e.g. those large un-interpersonal classroom environments, or workshops led by an un-empathic instructor). However, perhaps an "un-empathic" reputation of a professor is not dispositional, but instead is attributable to time constraints faced by this professor (e.g. the professor who sees time put into research as more tenure-worthy compared with time put into instruction and formative feedback, why bother with the latter?). Department heads can alleviate some of the professor's work load through hiring additional staff, teaching assistants, or by leveraging graduate students, potentially enabling time to increase interpersonal elements of instruction (e.g. time in office hours). A final tactic may be to have faculty reflect on the value of empathy, similar to the small-group interview method used in Chapter 2. In essence, through guided discourse, engineering faculty may develop their own perception of empathy's utility within their research or teaching. The efficacy and impact of such interventions would, again, be a fruitful area for future investigation.

**Range: Empathy within engineering as compared to empathy outside of engineering**

Sanders' (2009) discourse was within the TU Delft proceedings on designing for, with, and from user experiences. In a similar framework situated in engineering (engineering *for, with,* and *as* people) empathy plays a particularly unique role. In this framework, Fila et al. (2014) and Hynes and Swenson (2013) depict the role of engineering *with* people as having two facets: (a) individuals who make the decisions versus (b) individuals who face the consequences of the decisions. Fila et al. (2014) identified three key challenges to the process of engineering *with* people. These challenges included (a) stakeholders with homogeneous versus heterogeneous sets of needs, (b) external competition versus collaboration, and (c) absence of the stakeholder versus inclusivity of the stakeholder. Empathy may play a key role in working through these challenges.

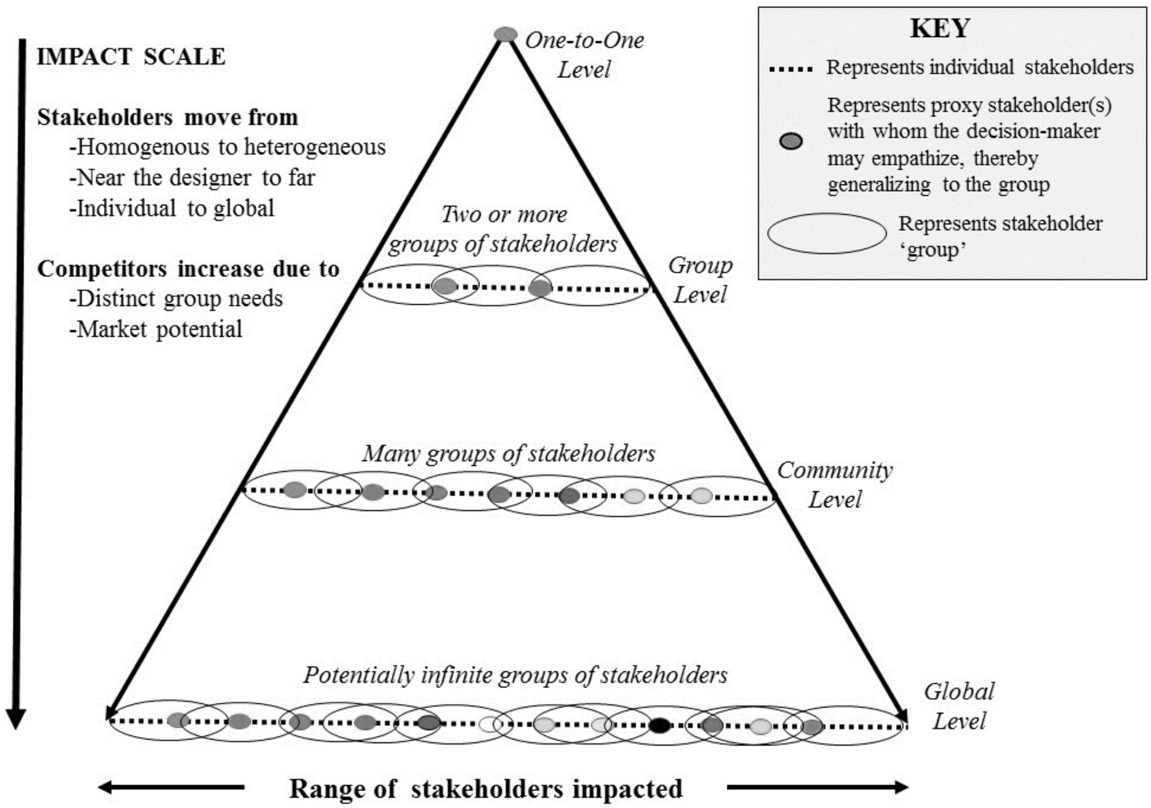


**Figure 5.3**: *Depicting how empathy might function within an engineering context*

Figure 5.3 provides an overview of how these challenges vary along what I have called the 'impact scale'. This impact scale increases as a greater number of stakeholders become involved in the outcome of an engineering decision. As the number of stakeholders increases, so too does the number of impacted stakeholder groups. These stakeholder groups have increasingly diverse or heterogeneous sets of values, which relate directly to a greater complexity of needs. As the scale moves from an individual stakeholder to a 'global' group of stakeholders, the proximity of the engineer to the collective impacted stakeholder groups also increases.

Within engineering, there tends to be at least multiple stakeholders directly impacted by the outcome of an engineering decision, so engineers tend to operate at least at the group level. As Figure 5.3 shows, the complexity of the outcome becomes wholly uncertain as more and more groups become potentially impacted by the engineering outcome. Problems at the global level tend to have elements of wickedness, where the resulting outcome cannot likely be known with certainty and it is tied to numerous other problems (Hess, Brownell, Dale, 2014; Seager, Selinger, & Wick, 2012). This is not to suggest that problems at the one-to-one level (e.g. nurse-to-patient; engineer-to-single user) may not exhibit elements of wickedness: as argued by Cotkin (2010), seemingly small or mundane issues can compile and escalate to the point where the 'most ethical' course of action becomes blurry and uncertain.

Figure 5.3 provides a depiction of how empathy's functioning within an engineering context might differ from empathy as described in traditional contexts. For example, in nursing or counseling, the focus tends to be on nurse-client or counselor-client relations (which are at the one-to-one level) due to the immediacy of feedback required in these work interactions. If a patient expresses distress, the nurse our counselor responds in situ. In contrast, within engineering, empathy seems to play an equally important, if not a stronger role in rationalization or justification within a decontextualized decision-making process, and the final engineering outcome generally impacts numerous stakeholders. These are stakeholders with whom an engineer may never directly interact with, and the vast majority of their interactions they do have may be asynchronous or markedly decontextualized.

As empathic design methodologies are traditionally depicted as single-client-centric, perhaps fostering or applying empathy for a 'group' of stakeholders requires empathy for a specific stakeholder or subset of stakeholders. This person-centric empathic awareness may guide generalizations made from empathic understanding of a single user or group of users onto the whole group. In this sense, what Figure 5.3 indicates is that 'proxy' stakeholders serve as reference points to generalize to that entire group. Empathic design strategies, which may require intimate personal interactions (e.g. close observation, interviewing, immersion) with a group of individuals, may be used to generalize to that group as a whole.

If one reflects on their own experiences, this is likely true. If you only know one individual with a particular disease, in your perception, that individual becomes representative of the whole group of stakeholders with that disease. However, the accuracy of this generalizability is likely questionable, missing some important distinctions across related stakeholders. Similar to 'data saturation' limits of qualitative inquiry, perhaps one must have experiences with some minimal number of individuals within a group to reliably generalize needs or desires to that stakeholder group. Even then, it is likely that not all needs are universal across a stakeholder group.

Engineering solutions tend to impact at least the group level, so an engineer who is within the mindset of the one-to-one level is likely excluding the needs and perspectives of stakeholders who may be indirectly impacted by an outcome. A pervasive and related notion throughout design literature is on personas. As stated by Adlin and Pruitt (2006), "Personas are detailed descriptions of imaginary people constructed out of well-understood, highly specified data about real people" (p. 3). Personas are useful for giving a designer (and engineer) a specific and static user-context to design for, and as such, are a technique that may allow an engineer to identify a "proxy" stakeholder or reach the "one-to-one" level in Figure 5.3. Humans naturally tend to categorize their understandings into groups in a manner similar to this, yet, in so doing we tend to overgeneralize (sometimes rationally, but often, if not more often, irrationally, e.g. see Allport's [1954] seminal work on the nature of prejudice). The development of personas allows one to simplify the complexity of human nature and provides a 'target' towards which empathy may be directed. However, in the process of trying to develop a persona, designers are cautioned to avoid de-humanizing a user in the ultimate pursuit of "the user" (e.g. read about Granny T in Kwok-Leung Ho, Ma, and Lee [2011]).

Due to the numerous stakeholders impacted by engineering outcomes, it is possible that any personal interaction with impacted stakeholder groups never occurs. As a result, the needs of these stakeholders may not be readily apparent, or the engineers' interpretations of the users' needs may be misguided. As framed in Fila et al. (2014), the stakeholder may be 'absent' from the engineer's decision-making process. To alleviate this difficulty, and for empathy to perform its epistemic functions (Oxley, 2011), it is likely that *some* interaction with stakeholders within a target group must occur for 'empathic design' to occur, and that *more* interaction with a greater number of stakeholders in this group might ultimately be better to accurately understand those needs. Yet, essential to this empathic development are related mindsets (Sanders, 2009) such as open-mindedness (van Oudenhoven et al., 2003), a self-experiential awareness (Kwok-Leung Ho et al., 2011), and an awareness of prejudices or potential misconceptions (Allport, 1954). Otherwise, one is likely to succumb to empathic biases (described in the next section) and ultimately not “see” the real individual, but rather “the user” (e.g. the fictitious user-persona that a designer or engineer mentally creates, see Kwok-Leung Ho et al. [2001]).

An extra challenge seems to present itself if the ‘stakeholder’ or stakeholder group of concern does not have a theory of mind or is a non-sentient being. Empathy’s most advanced cognitive functions, where one tries to depict how that agent rationalizes some situation, may not work whatsoever. In these contexts, it is possible that a separate, cognizant stakeholder may serve as the source for generalizing to that non-sentient or non-cognitive stakeholder. I’ve seen this happen in the ethics course described in Chapter 4, most prominently during in-class discussions related to the Deepwater Horizon Oil Spill case study when the instructors tasked students to consider the marine mammal’s perspective. Students literally could not do it. They seemed to feel as if the practice was silly; to them, since the mammal really could not reason (as students assumed this mammal lacked a theory of mind), they perceived the practice to be impossible. Commonly, these students would use a separate stakeholder, such as a marine biologist, as their focal point for projection or empathic perspective-taking. This distinction between rational and non-rational beings aligns with one of the most pressing considerations for empathy to perform its epistemic functions: empathic dispositions are not enough – one must also overcome empathic biases, particularly when the 'other' seems entirely different from one's self, not only demographically, but also cognitively.

**Biases: Why a focus on empathy alone may be insufficient**

de Waal (2009) notes, "Empathy builds on proximity, similarity, and familiarity, which is entirely logical given that it evolved to promote in-group cooperation" (p. 211). Likewise, Hoffman (2000) recognizes "here and now bias" as the tendency to empathize with those currently present, both spatially and temporally. This relates back to the 'basic' versus 'advanced' modes of empathy. The basic modes are automatic and activated when others are present, whereas the advanced modes require cognitive deliberation. In other words, when stakeholders are not immediately present, their needs will seem less pressing than the needs of those who are present.

In addition to 'here and now' bias, similarity and familiarity biases are equally important to recognize and alleviate. These biases direct ones tendency to empathize with select groups, namely those one unconsciously and automatically relates to at the detriment or negation of another. It seems that engineers may need an aptitude to empathize with those whom they are unfamiliar, particularly in a global context, if an engineer is to effectively integrate those stakeholders' needs into an engineering solution. On one hand, within the curriculum, engineering educators must take steps to alleviate dissimilarity or unfamiliarity barriers to empathizing. In the 'real-world', engineers must not only have the ability to empathize but the tendency to overcome barriers to empathizing with largely dissimilar others.

Generally speaking, differences between one human and another may be quite distinct. With an increase in globalization and mass communication has come what Rifkin (2009) calls a global empathic consciousness. Perhaps mass communication sources may help alleviate what Trout (2009) calls the 'empathy gap' or what President Obama denotes the 'empathy deficit' (from de Waal, 2009) through generating increased *familiarity* with others. While sometimes this increased familiarity may help alleviate some of the barriers for recognizing *similarities* between oneself and individuals from a distinct culture, depending on how that familiarity is ascertained, it may either alleviate or exacerbate perceived differences and stereotypes.

As an example, any 'classic' American war movie tends to pose the United States as the "good guys" and whomever it is the U.S. is fighting as the "bad guys". *American Sniper*, the most recent Hollywood blockbuster at the time of this writing, features Chris Kyle, a Medal of Honor recipient and Navy Seal. Throughout the movie, Chris snipes countless victims, Iraqi natives and soldiers, or the 'bad guys' as they are depicted in the movie. Wight (2015) questions the ethos of the film, particularly noting its powerful influence in instilling a sense of patriotism in the most unquestioning of Americans. Essentially, what the film creates is two groups. The way the film proceeds, the viewer is primed to empathize with the in-group (U.S. citizens and soldiers) at the dismay of the out-group (Iraqi people, including but not limited to soldiers).

This Hollywood-generated "in-group" bias (Hoffman, 2000) does not remain within the theater, but rather the viewer carries the bias outside of the theatre. Lacking any other experiences with an Iraqi native, one might leave the movie with the perception that Iraq as a country had done an incredulous injustice to the American people, and that the individuals within the country are fundamentally bad or evil. While more information or data could be gathered (e.g. reading how the Iraq war started in the first place, or how Iraqi people have suffered), to *empathize* with Iraq's individuals or Iraqi people as a group, one may need to interact with Iraqi natives. The most "accurate" empathy may stem directly from immersion within the world of the Iraqi people.

In-group bias, nonetheless, is not necessarily a *bad* thing. Take, for example, Obama's (2004) new introduction to his book *Dreams of My Father* when he mentions, "My powers of empathy, my ability to reach into another's heart, cannot penetrate the blank stares of those who would murder innocents with abstract, serene satisfaction" (p. x). Indeed, in-group bias is a tendency humans likely developed many ages ago as a sort of survival instinct (Ross, 2014). Even today, if we encounter a new culture or group of people, we are initially uncertain of how they will act, and even once we become cognizant of how their beliefs differ from our own we still are likely to feel that *our* ways are superior (Allport, 1954).

Helping engineering students realize unconscious biases (e.g. here-and-now, similarity, in-group) through guided self-reflection may be a first step for overcoming these biases and allowing empathy to be experienced towards a wider range of stakeholders. While requiring all engineering students to experience numerous cultures through programs such as study-abroad is likely not feasible, strategies identified in Chapter 4 have indicated that immersion within another cultural context is not the only mechanism for generating empathic tendencies. I explore other considerations (pulling largely from Chapter 4) in the following section.

**Development: Embedding empathy within engineering education**

Figure 5.1 presented "empathic" engineering outcomes, but these outcomes are the result of what empathy leads to as opposed to how empathy functions or developed at the individual level. Table 5.1 presents a depiction of empathy according to scholarly literature (note that this is a re-insertion of the empathic taxonomy from Chapter 4).

***Table 5.1***: *Taxonomy of empathy types*

| | Experiential & Affective | | Cognitive Processes |
|---|---|---|---|
| **Self-oriented** | ***Emotional contagion*** Holding a specific internal state as a result of another or others' states | ↔ | ***Role-taking or Projection*** Imagining how one would think and feel in the position of another |
| **Pluralism** | ↕ A duality between self and other orientations | | |
| **Other-oriented** | ***Empathic concern/joy*** Feeling concerned or happy for another or others | ↔ | ***Perspective-taking*** Imagining how another or others think or feel |

While Chapter 4 focused on the influence of specific critical incidents on perspective-taking tendencies, the mixing of the quantitative and qualitative data suggested that some of the derived themes did not show a direct relationship with perspective-taking. One of these was emotionally powerful activities and the other was projection or self-oriented perspective-taking activities. With this finding in mind, Figure 5.4 shows a reconfigured mapping of the empathic outcomes identified from thematic analysis of critical incidents in Chapter 4. The six themes pertaining to 'nature' of change are mapped corresponding to the empathy types depicted in Table 5.1. The reader should note, as was emphasized in Chapter 4, that these findings are highly preliminary and in need of follow-up studies of a more confirmatory nature.

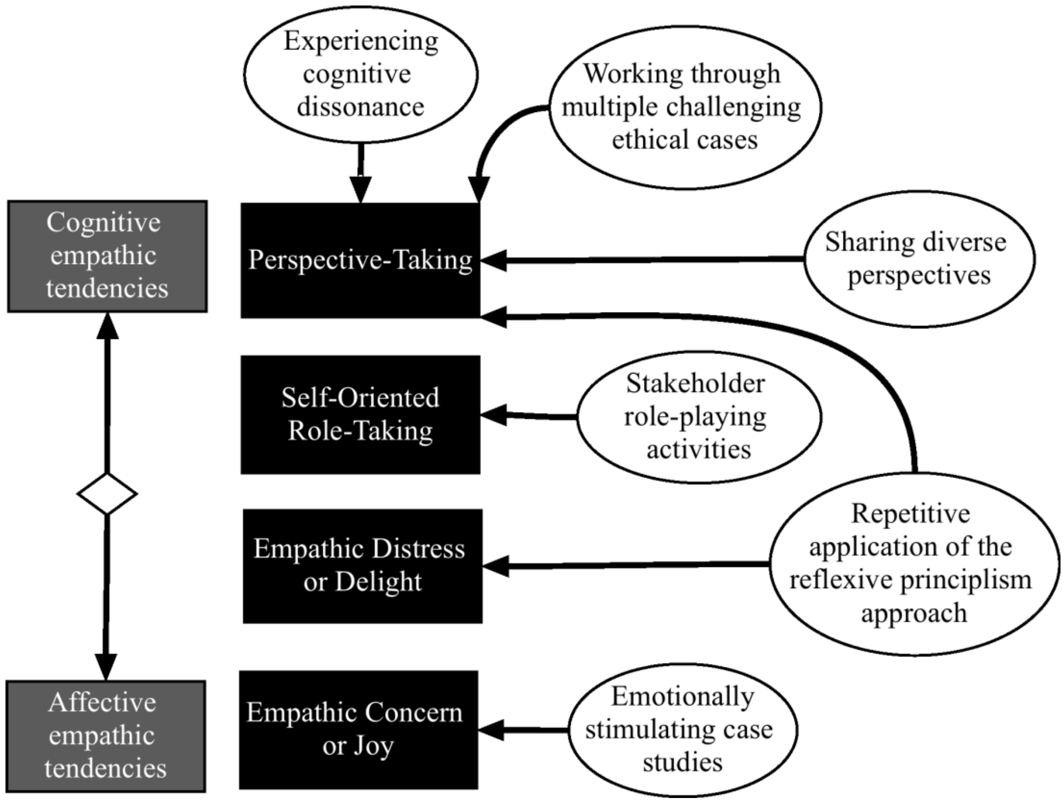


**Figure 5.4**: *Mapping curricular strategies to empathic tendencies*

Empathic concern, empathic distress, and role-taking were not the direct focus in Chapter 4, but Table 4.7 provided descriptive statistics pertaining to these sub-constructs. Perhaps the most surprising finding was that after participating in the course, students had significant decreases in personal distress (their self-reported likelihood to become anxious in tense situations). My best theory is that the reflexive principlism approach provided students with a process for reasoning through ethical issues *without* becoming over-distressed. Whether this theory holds true, this decrease in personal distress is intriguing in light of the pervasive negative relationship between personal distress and innovative behaviors (Hess et al., 2015).

However, it should be noted that personal distress as measured by the Interpersonal Reactivity Index is not the same as empathic distress in Hoffman's (2000) model, described as one feeling "distressed on observing someone in actual distress" (p. 4). The difference is personal distress does not require access to an actual "someone", whereas empathic distress is contingent upon another who is actively experiencing personal distress themselves. Further, empathic distress is likely to inspire helping behavior, whereas personal distress is not. Personal distress and empathic distress are likely related in that students who score higher on the personal distress measure are likely more prone to "feel tense" as a result of another experiencing distress. In contrast, students who score lower are likely to avoid becoming over-distressed in this situation and keep a calm mind. Yet, too low of a score on personal distress may indicate that students are not likely to develop a congruent emotion with a distressed individual whatsoever. These individuals may literally fail to *feel* the need to help another who is distressed. For Hoffman (2000), a congruent feeling of tenseness is essential to motivate a helping response. Paradoxically, if one becomes *too* distressed they are likely to look inwards and focus on helping themselves (e.g. alleviating one's own distress) rather than another. Developing a measure for empathic distress and exploring what is the optimal range of scores for this measure (in terms of inspiring helping behavior, particularly within an engineering context) will be a promising area for future investigation.

An equally intriguing finding was that students who expressed having emotionally powerful experiences did not see changes in perspective-taking tendencies. As depicted in Figure 5.4, I theorize that these experiences played a role more directly in empathic concern as opposed to perspective-taking. Based off the results, I further theorize that empathic concern may actually be detrimental to holistic perspective-taking, leading one to focus on a specific stakeholder group as opposed to all potentially impacted stakeholders. However, as shown by Fila and Hess (2014), empathic concern can play a key role in the design process, leading to the generation of user-centric criteria (largely, but not limited to criteria related to safety considerations).

This reader should not consider this thematic mapping as relevant only within an ethics course. For example, **role-playing** is common within engineering design. Johnson et al. (2014) used an ‘empathic experience design’ to get the designer into the mindset of the user, and found that this act of projection sparked students’ creativity. Likewise, Leydens and Lucena (2009) suggest a direct focus on listening within engineering education would enable students to more effectively integrate community needs into their engineering processes – a suggestion that aligns directly with the **sharing diverse perspectives theme**. This naturally requires students to situate or immerse themselves in the community. Lastly, **cognitive dissonance** seems to align with the ‘critical’ experiences described in Zoltowski, Oakes, and Cardella’s (2012) – these ‘failure’ experiences led students to think about the design task from a completely new mindset.

Engineering educators are implementing a number of practices throughout engineering curriculum to foster students’ empathic sensibilities, even if the term 'empathy' is seldom explicitly stated. An explicit focus on developing empathy throughout the engineering curriculum will have numerous benefits, as described by the participants within this study. As educators encourage the engineers of tomorrow to embody these skills, in turn, these engineers will help create a brighter future for generations to come. The next challenge for researchers is to continue this line investigation to determine which curricular strategies have the greatest impact on the development of engineering students' empathic tendencies. This pursuit, along with other areas of investigation, I describe in the following section.

**Implications: The value of embedding empathy across engineering education**

The three studies within this dissertation highlighted potential pathways and improved outcomes of an empathically guided engineering process and educational design strategies for prompting critical experiences to develop engineering students' empathic perspective-taking tendencies. Taken together, these results indicated that the development of empathy throughout engineering education is possible. Furthermore, as indicated by participants in Chapters 2 and 3, the development of engineers' empathic tendencies may benefit a broad spectrum of stakeholders including but not limited to engineering students, practitioners, stakeholders of engineered projects, higher educational institutions, engineering organizations, and accreditation bodies. The benefits of developing more empathic engineers are widespread and nuanced, improving both internal functioning (e.g. within team environments or managerial relationships) and the broader impact of engineering decisions (e.g. meeting clients' needs or considering social impacts of engineering outcomes).

Practitioners' survey responses within Chapter 3 indicated that as engineers increased in years of experience, they became more cognizant of the role of empathy and care in their work and they began to consider empathy and care as core to their practice. This finding alone indicates that engineering curriculum may drastically improve by educators' direct focus on the development of empathy and care across their student population. While Chapter 3's results indicated that engineering education had a slightly negative impact on the development of participants' empathic or caring tendencies, results from Chapter 4 found means through which developmental changes in students' empathic perspective-taking may be attainable at the post-secondary level.

Several ABET student outcomes may be indirectly satisfied by a focus on the development of engineering students' empathic tendencies (including but not limited to perspective-taking). As an example, empathy was described by practitioners as key to generating design solutions that meet users' needs (ABET outcome c), fostering interpersonal relations (ABET outcomes d and g), a "broader" contextual awareness (ABET student outcome h), and making ethical decisions (ABET outcome f).

Yet, the development of 'empathic engineers' has benefits far beyond ABET defined outcomes. Empathic engineers not only improve team functioning, they make it possible (see Chapter 2). Not only do empathic engineers aspire to meet users' needs, they strive to generate optimal solutions (see Chapter 3). Within industry, the most effective leaders tend to exemplify empathy and care (see Chapter 3). Empathic engineers may be especially key in a world that is becoming more global, as empathic perspective-taking development led to students' open-mindedness towards novel ways of knowing and being (see Chapter 4). This open-mindedness is key for overcoming empathic biases and being receptive to novel ways of knowing and being (see section on biases).

As a starting place, educators seeking to develop empathic perspective-taking within their courses or curriculum may use the pedagogical framework and ethical approach described in Chapter 4. Educators will need to challenge students to work collaboratively through multiple and diverse ethical issues of interest (multiple cases will ideally lead to 'reflexivity' and diverse cases will ideally capture a broad range of interests). The most critical component, as indicated by the results in Chapter 4, will be fostering a mindset in which students are receptive to novel ideas and facilitating the sharing of diverse perspectives. This receptivity may be developed through stakeholder perspective-taking or 'role-playing' activities, whereas effective discourse may be accomplished through in-class discussions, asynchronous on-line posting, and/or challenging students to develop a solution within a group and to justify that decision in light of ethical principles and stakeholder perspectives. This pedagogical practice could take place within multiple contexts (e.g. high school, first-year engineering, graduate level engineering coursework, workplace training), although (as a caution due to the low sample size in Chapter 4) the efficacy of these practice ought to be evaluated and refined in light of the results.

**Future Research**

Overall, this dissertation has sparked many more questions than answers. While these chapters have highlighted the salience of empathy and care within engineering, they have also revealed a greater need for future investigations on these phenomena within an engineering context. The primary research foci emerging from this dissertation fall in five key groups: (a) empathic processes, (b) developmental strategies, (c) evaluative techniques, (d) comparative studies, and (e) organizational impact. In many respects, these research pursuits overlap, so 'prioritization' of one research topic over another is not necessarily feasible. Rather, one line of work may preclude another. For example, valid measures for empathic measurement will enable the exploration of engineering students' empathic development.

**Empathic processes**

This line of research would focus on how empathy manifests itself throughout engineering or design processes. One line of research that Fila and Hess (2014) have already begun seeks to develop an empathic design model that explores how empathy manifests itself throughout the design process of students and practitioners. A separate line of work would be to develop a path analysis of emergent empathic outcomes to relational and engineering outcomes (e.g. to refine and validate Figure 5.1). A more specific research endeavor, relating intrapersonal and engineering outcomes, would be to synthesize the role of empathy in ethical reasoning, particularly as empathic perspective-taking applies to the reflexive principlism approach.

**Developmental strategies**

This area of research is a direct extension of Chapter 4. The most immediate areas of research are (a) to continue exploring critical incidents that sparked shifts in perspective-taking, (b) to validate experiences identified within Chapter 4, (c) to deduce what other critical experiences enhance perspective-taking tendencies, and (d) to explore the magnitude of impact of critical experiences on empathic development. Going beyond the course context and perspective-taking development, researchers may focus more holistically on students' curricular experiences. For example, a research objective may be to determine how distinct curricular experiences (e.g. service-learning, project-based learning, study abroad experiences, extra-curricular activities) influence the development of empathic tendencies. It is possible that a focus on certain skill sets would indirectly enhance certain empathic tendencies. In this sense, a research objective may be to depict corollary skills engineering educators should focus on if hoping to foster empathy amongst their students (e.g. innovative behavioral tendencies, interpersonal skills).

**Evaluative techniques**

A third area of research is to develop empathy instruments or techniques that are engineering specific. In other words, one research pursuit is to develop and validate a psychometric instrument for evaluating engineering-specific empathic behaviors or tendencies. Other research areas would include the refinement of existing instruments. The research pursuit our team has already begun (see Hess et al. [2014]) and will continue is refining and validating the Ethics Transfer Case methodology to explore developments in perspective-taking. Engineering educators may develop similar techniques for evaluating empathic development throughout other areas of engineering education (e.g. within a service-learning, global design, or community design course).

**Comparative analyses**

Comparative studies might take the form of cross-case comparisons, where the 'cases' as defined vary. First, this work may include a comparison of empathic tendencies or perceptions across engineering demographics, including by profession and across institutions. It is possible that these results would identify if there are areas or disciplines within engineering where empathy and care are already commonplace, and these disciplines could be exemplars for other disciplines to follow. Second, this work may take the form of an exploration of how the perceived importance or existence of empathy throughout other STEM fields compares to perceptions within engineering. These results would inform whether there is misalignment between 'outsider' perceptions to those 'within' engineering. Lastly, this work could compare empathic tendencies (as measured through existing instruments or novel instruments) across STEM disciplines and stakeholder groups, such as faculty, practitioners, and students. Chapter 3 examined perceptions, but it would be interesting to see whether engineers actually become more or less empathic with an increase in experience.

**Organizational impacts**

A final research domain would be to explore the impact of a more empathic or caring educational institution or classroom culture on recruiting and retaining diversity throughout higher engineering education. How this is measured would vary, but this research could align with existing NSF programs such as ADVANCE, where the focus is on recruitment of more women faculty throughout STEM and improvement of women faculty's experience as professorate. Beyond higher education, this 'organizational impact' focus may shift to engineering organizations. As an example, one research objective may be to explore the impact of a more empathic employee or leadership population on organizational revenue, customer satisfaction, and associated variables. If empathy is as important for success as participants indicated in Chapter 3, then this line of work would be highly valuable as the world continues to become ever-more global.

## CLOSING ACKNOWLEDGEMENTS

The support I received from my committee members, my instructors, my colleagues, and my loved ones made this dissertation possible. Thank you to everyone who has provided me encouragement and support throughout this endeavor.

Discourse sparks change by bringing to light new perspectives and mindsets. As the identified future research foci indicate, there is still much territory for exploration. I hope this discourse has illuminated a path for others to focus on this area of inquiry, and to ultimately bring about the changes needed to realize a more equitable, loving, and sustainable world.

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APPENDICES

Appendix A: Chapter 3 Interview Protocol

1. What does "empathy" mean for you? *We are particularly interested in how you define it because we are interested in the differences in definition. We don't want to limit you*.
    a. What has influenced your understanding of empathy?
    b. Can you give an example of where "empathy" is present?
2. What does "care" or "caring" mean? *We are particularly interested in how you define it because we are interested in the differences in definition. We don't want to limit you*
    a. What has influenced your understanding of care or caring?
    b. Can you give an example of where "caring" is present?
3. How does empathy show up differently than care?
4. How do you show or express empathy and care in your work context? (If at all)
    a. How are these skills necessary for you, as an engineer, to be successful?
5. Describe a particular context/situation in your work where these constructs are relevant?
    a. *(Contextual Criteria!) Did they take ownership of the initial response? If so, ask*
        i. How would you say that other people would assess the situation different/similarly?
    b. *(Contextual Criteria!) If they externalized the initial response, instead ask*
        i. How would you say that YOU would assess the situation different/similarly?
    c. When was there value in the presence of these constructs in these situations?
    d. Do you have examples where being empathetic and caring provided you with a competitive edge/or disadvantage?
        i. *(Contextual Question!) I'm hearing a lot of positive responses. Are there any ways that embodying these traits put you at a disadvantage? Why or How?*
6. How are empathy and care important for your discipline? You may differentiate (i.e empathy is important and care is not)
    a. What about engineering as a whole?
    b. Are there certain aspects of your work where these constructs are more important than others?
    c. What about YOU as a person…

7. Rank Engineering on a scale of 1-10 of being empathetic/caring, with 1 as being very low and 10 as being very high.
    a. Where, on this scale, would you say engineering should be, ideally?
    b. *Why the difference? OR Why the same?*
    c. How could empathy and care be better promoted in engineering?
8. How caring were your faculty/advisors when you were a student?
    a. What is it that you experienced?
    b. How did this impact you as a student, in general?
    c. How did this impact you as a student, in terms of becoming more or less empathetic/caring?
    d. How could empathy and care have better been taught in engineering education?
9. Do you have any advice on…
    a. Means through which empathy and care could be incorporated more into your daily work?
    b. Alternative keywords that capture your understanding of empathy and care in an engineering context?
10. Do you want to add anything that you feel is important and we didn't ask?

# Appendix B: Empathy and Care Survey Overview

Based on your experiences in engineering, rank how important it is for engineers to show empathy and care in the following situations. (6-point Likert scale)

1. Working in teams, $\bar{x}$ = 5.00, s = 0.97
2. Meeting a client's needs, $\bar{x}$ = 5.40, s = 0.86
3. Communicating with others, $\bar{x}$ = 5.26, s = 0.85
4. Listening to others, $\bar{x}$ = 5.37, s = 1.45
5. Ensuring that a design meets environmental regulations, $\bar{x}$ = 4.27, s = 1.29
6. Ensuring that the jobsite/work place is safe, $\bar{x}$ = 4.87, s = 0.83
7. Treating others respectfully, $\bar{x}$ = 5.39, s = 1.19
8. Making ethical decisions, $\bar{x}$ = 5.22, s = 1.39
9. Performing community service, $\bar{x}$ = 4.18, s = 1.39
10. In your design work, $\bar{x}$ = 4.07, s = 1.39
11. Stakeholder considerations, $\bar{x}$ = 4.48, s = 1.25
12. Sustainability considerations, $\bar{x}$ = 4.21, s = 1.24

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, $\bar{x}$ = 80.93, s = 16.29
14. Care, $\bar{x}$ = 83.93, s = 14.76

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, $\bar{x}$ = 72.63, s = 20.03
16. Care, $\bar{x}$ = 77.51, s = 18.42

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. $\bar{x}$ = 5.08, s = 1.08
18. I believe traits associated with empathy and care can be learned. $\bar{x}$ = 4.37, s = 1.169
19. I learned to be more empathetic and/or caring during my work as an engineer. $\bar{x}$ = 3.56, s = 1.56
20. I learned to be more empathetic and caring during my college years. $\bar{x}$ = 2.92, s = 1.28
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*) $\bar{x}$ = 4.75, s = 1.33
22. I do not think the engineering industry needs to be more empathetic/caring. (*Reverse coded for analysis*) $\bar{x}$ = 4.68, s = 1.29
23. Empathy and care is present in my work as engineer. $\bar{x}$ = 4.73, s = 1.05

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. $\bar{x}$ = 4.31, s = 1.22
25 My bosses value employees that are empathetic and caring. $\bar{x}$ = 3.79, s = 1.35
26 My colleagues show empathy and care towards clients when s/he interacts with them. $\bar{x}$ = 4.20, s = 1.06
27 My colleagues show empathy and care when we work as a team. $\bar{x}$ = 4.27, s = 1.01
28 My professions involves the consideration of empathy and care. $\bar{x}$ = 4.02, s = 1.28
29 I am aware of policies on empathy and care at my work. $\bar{x}$ = 3.48, s = 1.66
30 I am aware of policies on empathy and care in my profession. $\bar{x}$ = 3.21, s = 1.53
31 I believe safety considerations involve caring. $\bar{x}$ = 4.68, s = 1.33

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. $\bar{x}$ = 4.59, s = 1.19
33 Engineered products will be more environmentally friendly. $\bar{x}$ = 4.31, s = 1.28
34 There will be more mutual understanding, respect and trust between people involved. $\bar{x}$ = 4.75, s = 1.16
35 Engineered products will be more successful in the marketplace. $\bar{x}$ = 4.22, s = 1.29
36 Stakeholder considerations will become more central to engineering designs. $\bar{x}$ = 4.15, s = 1.30
37 Engineering will attract more females. $\bar{x}$ = 3.59, s = 1.47

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

Appendix C: Chapter 4 Engineering Ethics Course Syllabus

**Solving Ethical Problems in Engineering: A Course in Multidisciplinary Engineering Ethics**
**Spring 2014 Thursdays, 4:30 to 5:45 PM, MJIS 1083**
**BME 59500 (1 credit)**

**Course Description**: The focus of the course is on increasing ethical awareness and developing ethical reasoning within the engineering profession by introducing students to critical issues in engineering ethics. Students will analyze a carefully selected set of four case studies that includes both historic cases and new cases focused on emerging technologies in several engineering disciplines. Students will use a framework and method for analyzing ethical dilemmas that are particular to engineering. This methodology, called Reflexive Principlism, is based on a set of common moral principles as ethical starting places. In this framework, the common ethical principles are applied in an iterative process of analysis and decision-making that is similar to the engineering design process. Students will be encouraged and facilitated in engaging with peers, colleagues, and experts as part of analyzing the case studies. These ethical reasoning practices are essential for future engineers, and are gaining greater visibility as industries, professional organizations, and funding agencies begin to recognize their value to ethical professionalism.

This course is open to seniors and graduate students from all engineering disciplines. The course will meet for 12 active learning sessions (75 min. each). Students will be expected to prepare for each session by engaging with course content via an online environment (Pearson's Open Class). The instructors will use several assessment instruments to measure student's development of ethical reasoning. The outcomes of these assessments are for student self-evaluation and for evaluation of course material and specific answers will not be graded. Grading will be based on student participation and full completion of all components of the course. Students will participate in one 30-60 minute interview after the course as part of the course development.

Learning Outcomes: Upon completion of the course students will be able to:
a) identify and describe ethical dilemmas in the context of historical and developing technology and engineering practice,
b) follow a structured, iterative decision-making process for ethical reasoning to reach a supported conclusion regarding ethical dilemmas, and
c) use their own reflection on the ethical reasoning process within multiple case studies to re-evaluate the coherence between the principles, codes, and theories involved in any given case.

Instructors:
- Andrew Brightman, PhD, aob@purdue.edu, ph. 496-3537
- Michael Hiles, PhD, hiles@purdue.edu, ph. 427-7337
- TA: Andrew Iliadis, MA, ailiadis@purdue.edu, ph. 714-2651

Other invited speakers:

- Jonathan Beever, PhD, The Rock Ethics Institute, Penn State University
- Matthew Krane, PhD, Assoc. Professor of Materials Engineering, Purdue

**Required Text**: None. However, there will be required reading and viewing content assigned for each case study and accessed online (Pearson's Open Class).

Weekly Online Reflections and Discussion: On most weeks, one or more reading and/or video viewing assignments will be posted for you to read and respond to before the next class.

**Assessment**: Each case study will include learning-assessment activities in addition to the assessment instruments noted above. Grading is based entirely on participation in all course activities including online assessments, quizzes, 4 team reports, and postings covering reading assignments, lectures, and previous class discussions.

| **Dates** | **Topics (NOTE: schedule subject to change)** |
|---|---|
| Jan. 16 | Pre-course Assessments: DIT2/ERI/Survey/Case (online)<br>Introduction to Engineering Ethics Course Plan |
| Jan. 23 & 30 | Reflexive Principlism as a Framework for Ethical Decision-Making |
| Feb. 6 | Diagram and Quiz (online) - no class |
| Feb. 13 & 20 | Case Study I - Designing a Tissue-Engineered Pediatric Heart Valve (MH) |
| Feb. 27 | Case Study report 1 due - no class |
| Mar. 6 & 13 | Case Study II - Kansas City Hyatt Regency Skywalk Collapse (MK) |
| Mar. 20 | SPRING BREAK / Case Study report 2 due 24th – no class |
| Mar. 27 & 3 | Case Study III - How a Diagnostic Device Became a Disease (AB) |
| April 10 | Case Study report 3 due – no class |
| April 17 & 24 | Case Study IV - BP Deepwater Horizon Oilrig Explosion and Leak (JB) |
| May 1 | Case Study report 4 due – no class / Interviews & Post-course Assessments |

| **Assignments for completion** | **Points** | **Grading Scale** |
|---|---|---|
| Pre-course: DIT2/ERI Assessment | 4 | A+ = (>96%) |
| Pre-course: Survey of ethics background and satisfaction | 4 | A = (>92%) |
| Pre-course: Ethics Case Study | 4 | A- = (>89%) |
| Ethical reasoning diagram and Quiz: Reflexive Principlism | 8 | B+ = (>86%) |
| Quick-checks: case content and ethics concepts evaluation | 8 | B = (>82%) |
| Case study report 1: team-based decision / justification | 8 | B - = (>79%) |
| Case study report 2: team-based decision / justification | 8 | C+ = (>76%) |
| Case study report 3: team-based decision / justification | 8 | C = (>72%) |
| Case study report 4: team-based decision / justification | 8 | C- = (>69%) |
| Peer review of participation in 4 case studies / reports | 8 | D = (>60%) |
| Weekly online discussion and posting participation | 12 | F = (below 59%) |
| Personal Interview | 8 | |
| Post-course: DIT2/ ERI Assessment | 4 | |
| Post-course: Survey of ethics background and satisfaction | 4 | |
| Post-course: Ethics Case Study | 4 | |

# Appendix D: Chapter 4 Perspective-Taking Activities

**Case 1: Tissue Engineered Heart Valve**

1. Who are all the stakeholders involved in this case?

2. Taking the perspective of a stakeholder other than an engineer in the company, describe which design should be developed and implemented. Be sure to clearly identify your selected stakeholder. In your posting consider addressing the following questions:

   a. How is the perspective of the stakeholder you are representing biased in their thinking?

   b. Is the risk of releasing the MVU with known potential defects acceptable to this stakeholder?

   c. Is the company always obligated to release the best quality product? What if THS did not exist?

   d. If all the engineering managers in the company are wealthy US citizens with health insurance, can they best decide this issue for all stakeholders?

   e. While the managers might want the best treatment and outcome for their own children, can they demand it?

   f. How do you weigh efficacy of treatment with number of patients treated?

   g. Is the right to decent minimum healthcare being considered?

   h. Does it matter that the devices being considered are potentially life-saving?

**Case 2: Kansas City Skywalk**

1. Based on what you know of the case so far, what do you think would be an appropriate perspective for an Engineering Professional Society associated with this case?
2. What actions, if any, do you think they should take?
3. Which aspects, if any, of the Code of Ethics for Structural or Civil Engineers apply in this case and why

**Case 3: Osteopenia Case**

Choose one of the following stakeholders...

(a) a medical device engineer, (b) a physician working with medical device companies, (c) a regulatory officer of a federal agency such as the FDA, or (d) a patient needing treatment from newly developed medical technology

From the perspective of your chosen stakeholder, respond to the following statement:

The way to resolve the ethical dilemmas surrounding conflicts of interest in engineering better medical therapies is…

**Case 4: Deepwater Horizon**

1. How do we weigh the various stakeholder claims in this case?
2. Do professional engineers have the option or obligation to say “no” to projects with unlikely but significant risks? Why or why not?

Appendix E: Interpersonal Reactivity Index (M. H. Davis, 1980, 1983)

The following statements inquire about your thoughts and feelings in a variety of situations. For each item, indicate how well it describes you by choosing the appropriate letter on the scale at the top of the page: 1, 2, 3, 4, or 5. When you have decided on your answer, fill in the letter on the answer sheet next to the item number. READ EACH ITEM CAREFULLY BEFORE RESPONDING.

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Does not Describe me Well | | | | Describes me Very well |

1. I daydream and fantasize, with some regularity, about things that might happen to me. (FS)
2. I often have tender, concerned feelings for people less fortunate than me. (EC)
3. I sometimes find it difficult to see things from another's point of view. (PT) (-)
4. Sometimes I don't feel very sorry for other people when they are having problems. (EC) (-)
5. I really get involved with the feelings of the characters in a novel. (FS)
6. In emergency situations, I feel apprehensive and ill-at-ease. (PD)
7. I am usually objective when I watch a movie or play, and I don't often get completely caught up in it. (FS) (-)
8. I try to look at everybody's side of a disagreement before I make a decision. (PT)
9. When I see someone being taken advantage of, I feel kind of protective towards them. (EC)
10. I sometimes feel helpless when I am in the middle of a very emotional situation. (PD)
11. I sometimes try to understand my friends better by imagining how things look from their perspective. (PT)
12. Becoming extremely involved in a good book or movie is somewhat rare for me. (FS) (-)
13. When I see someone get hurt, I tend to remain calm. (PD) (-)
14. Other people's misfortunes do not usually disturb me a great deal. (EC) (-)
15. If I'm sure I'm right about something, I don't waste much time listening to other people's arguments. (PT) (-)
16. After seeing a play or movie, I have felt as though I were one of the characters. (FS)
17. Being in a tense emotional situation scares me. (PD)
18. When I see someone being treated unfairly, I sometimes don't feel very much pity for them. (EC) (-)
19. I am usually pretty effective in dealing with emergencies. (PD) (-)
20. I am often quite touched by things that I see happen. (EC)
21. I believe that there are two sides to every question and try to look at them both. (PT)
22. I would describe myself as a pretty soft-hearted person. (EC)
23. When I watch a good movie, I can very easily put myself in the place of a leading character. (FS)
24. I tend to lose control during emergencies. (PD)
25. When I'm upset at someone, I usually try to "put myself in his shoes" for a while. (PT)
26. When I am reading an interesting story or novel, I imagine how I would feel if the events in the story were happening to me. (FS)
27. When I see someone who badly needs help in an emergency, I go to pieces. (PD)
28. Before criticizing somebody, I try to imagine how I would feel if I were in their place. (PT)

Appendix F: Chapter 4 Ethics Transfer Case Activity

Heating with wood is a time-honored and practical tradition in forested areas and has been making a comeback in Maine. A greater percentage of homes in Maine use wood as their primary heat source – 14 percent – than any state other than Vermont. An estimated 50 percent of Maine homes also use wood as a supplemental heat source. The trend is helpful for cutting expensive oil bills, but not for increasing air quality. Typical wood stoves emit more of the pollution that aggravates asthma and other respiratory conditions than the oil and gas heating systems they are meant to supplement or replace.

Twenty-six years ago the U.S. Environmental Protection Agency (EPA) set emission standards for wood heaters at 7.5 grams per hour. Some states have already set stricter standards, such as Washington's 4.5 grams per hour. Several states, not including Maine, have filed a notice to sue the EPA for failing to revise its outdated standards for residential wood heat. As a result, the EPA has proposed a new standard for 2019; 1.3 grams per hour. This is even lower than the level achieved by one of the top stove designers in Maine who has just completed an extensive redesign for efficiency and air quality on a new wood stove, which still emitted 2.3 grams per hour.

There are at least 7 million older-technology stoves currently being used throughout the United States. This past year, fewer than 74,000 new units were sold across the country. A well-built wood stove lasts for generations, so even if the EPA does decide to double down on the regulations, switching out all the old-style stoves with cleaner models will take some time. In addition, one wood stove manufacturer estimated that it will cost nearly $1 million to re-engineer its stoves to meet the 2019 standards and could drive up the cost of a stove by 25 percent.

Another option proposed to the EPA by this wood stove manufacturer representative is to implement a wood stove change-out program. During the summer of 2013, some wood stove dealers offered $300 credits to people who exchanged their old stove for a new one, which sells for between $1,000 and $3,000. These buyers also gained a $300 federal rebate. This federal rebate is expired as of 2014, although some rebates are still offered at the state level, such as the $250 Efficiency Maine rebate.

Both engineers and policy-makers face complex ethical decisions in this case. Imagine that you are the lead engineer with one of the top wood-stove manufacturers in the State of Maine and a consultant with the EPA. **How would you reason through advising your company on the most ethical course of action?**

For more information on this case click here.

**Task:** Create a diagram or flowchart of your thought process that led to and supports your conclusion. Upload this diagram using the link below. You can create your visualization in the manner that you feel most comfortable. For example, you could (a) create a PowerPoint slide or Word file, (b) draw the diagram by hand, take a picture of it or scan it and submit, or (c) a basic graphics program such as MS Paint.

Along with your visualization, describe each of the steps you used to come to your decision. The minimum acceptable response will be about 100 words.

Provide a brief explanation of why you used these steps to make your decision. The minimum acceptable response will be about 100 words.

Would you need any other information to improve your decision? If so, what is it and how would you obtain it?

Please identify any external sources that you used to inform and support your decision and how you obtained these materials.

Appendix G: Chapter 4 Ethics Transfer Case Rubric

| Category | Item | POINTS POSSIBLE 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|
| Justification | **Decision Made** | An explicit decision was proposed (4 pts) | An explicit decision proposed that was contingent on facts (not on values) (2 pts) | n/a | No solution proposed |
| | **Coherence** | There is evaluation of the relationship between multiple stakeholders, principles, and relevant codes/regulations | There is evaluation of the relationship between 2 of the following 3: multiple stakeholders, principles, and relevant codes/regulations | There is consideration of 1 of the following 3: multiple stakeholders, principles, and relevant codes/regulations | No rationale present. |
| | **Range of Implications** | **From the decision,** several long- and short- term ethical implications or thought-experiments considered. (e.g. this solution provides x with y) | From the decision, at least 2 short-term and/or long-term ethical implications considered. | From the decision, only 1 ethical implication explicitly addressed | No implications considered. |
| Identification | **Autonomy** | The response explicitly identifies respect for autonomy, or some aspect of this principle (e.g. supporting goals, cultures, upholding values, freedom of decision-making, valuing views) | | | |
| | **Beneficence** | The response explicitly identifies beneficence, or some aspect of this principle (e.g. making money, right thing, good action, doing good, benefits) | | | |
| | **Justice** | The response explicitly identifies justice, or some aspect of this principle (e.g. fairness, equality, basic needs, what is fair, due, or owed) | | | |
| | **Non-maleficence** | The response explicitly identifies non-maleficence, or some aspect of this principle (e.g. safety, protection of environment, health, avoiding harms, protecting) | | | |
| | **Conflicts of Principles** | 3 or more conflicts between principles identified | 2 conflicts between principles identified | 1 conflict between principles identified | No conflicts between principles identified |
| | **Central conflict** | The response identifies a value conflict **and** how that influences their decision process? (e.g. making money versus environmental protection) | | | |

*Chapter 4 Ethics Transfer Case Rubric Continued*

| Category | Item | POINTS POSSIBLE | | | |
|---|---|---|---|---|---|
| | | **3** | **2** | **1** | **0** |
| | **Level and accuracy of Specificity** | Specification is highly detailed, including a consideration of each of the 4 principles within the case constraints (e.g. explicitly defines autonomy given case constraints and describes how it differs from some other possible specification) | Specification is moderately detailed, including consideration of at least 2 of the principles and how these principles are relevant to the case | Specificity is abstracted from case detail (e.g. principles are not explicitly defined, but reference to some components of the principles in reference to the case is evident) | No detail of specification |
| **Specification** | **Rationale for balancing of value** | Response recognizes balancing of all 4 principles is necessary and makes a reasonable assessment of that prioritization based on the details of the case and level of impact. (e.g. autonomy is most important because x, beneficence is least important because of y) | response explicitly balances at least 2 of the principles (or components of 2 of the principles) | response is not explicit in their balancing of the principles but focuses most of their attention on 1 or 2 of the principles indicating prioritization of those | No rationale for prioritization. |
| | **Core value(s)** | **1** value is specified and explicitly prioritized in terms of principles as critical to the decision. (e.g. minimizing nonmaleficence by preventing air pollution) (4 pts) | **1** value is specified and explicitly prioritized as critical to the decision? (e.g. minimizing environmental impact by reducing air pollution) | At least one value is explicitly identified. (e.g. minimizing environmental impact) | No core value identified |

*Chapter 4 Ethics Transfer Case Rubric Continued*

| Category | Item | POINTS POSSIBLE | | | |
|---|---|---|---|---|---|
| | | 3 | 2 | 1 | 0 |
| Perspective Taking | **Stakeholder Identification** | More than 3 stakeholders identified | 2-3 stakeholders identified | 1 stakeholder identified (company counts as a stakeholder) | No stakeholders identified |
| | **Users' Needs** | 3 or more external stakeholders' needs are used to inform decision | 2 external stakeholders' needs are used to inform decision | 1 external stakeholder's needs are used to inform decision | No external stakeholders needs used to inform decision |
| | **Other-Oriented Application of Principles** | The response contrasts how at least 2 stakeholders would weigh principles differently. | 2 or more principles are used explicitly as a basis to reason from another stakeholder's perspective | The response explicitly considers the values of external stakeholders | The response does not consider the values of other stakeholders |
| | **Seeking feedback** | Does the response indicate a need for direct feedback from the stakeholders identified? | | | |
| Reflectivity | **Feedback Loops** | The visual or written response clearly indicates the final solution will feedback into earlier considerations and have to be reevaluated through the proposed framework | | | |
| | **Plans for Reevaluation** | The response suggests several decisions or considerations will need to be reevaluated based on additional information | The responses indicates at least 1 specific decision will need to be reassessed based on further information | The response indicates a general need for more information. | No objections considered |
| | **Solution Evaluation** | Strengths and weaknesses of the solution are assessed from 2 or more external stakeholders' perspectives (external meaning not the company) | Strengths and weaknesses of the solution are assessed from at least one external stakeholder's perspective | At least one strength *or* weakness of the solution is assessed from one external stakeholder's perspective | No strengths or weaknesses assessed from another perspective |

## Appendix H: Chapter 4 Interview Protocol

**INTRODUCTION**

I'd like to ask some brief questions to understand your experience in the class and your own learning of moral reasoning concepts. This interview should take about 45 minutes of your time. I will record the interview, and the recording will be transcribed and de-identified. Your course instructors will know whether you completed the interview to assign points, but will not have access to the de-identified transcripts until after the course is complete and grades have been assigned. General observations from the interviews will be used to improve future revisions and development of this course. If there are any questions you'd prefer not to answer you can simply request I move to the next question. Do you have any questions before we begin?

1. Can you tell me a little about your background? Are you a full-time student or a practicing professional? What is your field (of study / of practice)?

**GENERAL COURSE FEEDBACK**

2. What did you expect to learn in this course? Did the course meet your expectations?
    - What features would you like to see added to the course during future developments?
    - How would this feature help your ability to learn ethics or make ethical decisions?
3. Over the course of the semester, has your thinking or understanding of engineering ethics changed in any way? If so, how?

**ETHICAL REASONING**

4. Recalling the 4 principles of reflexive principlism – Respect for Autonomy, Beneficence, Non-maleficence, and Justice – did the process of reflexive principlism help you with ethical decision-making? *If so, how?*
5. After completing this course, are you more aware of ethical issues you have (or may have) encountered in your practice of engineering? Did it get easier to identify and articulate ethical issues as the course progressed?
    - *Can you provide any examples?*
6. How do you think this course will help you in making ethical decisions in your work?
    - Will you apply reflexive principlism outside of this course? *If so, where and how?*
    - If not, how will you go about making a decision if you face an ethical issue in your work?

**TRANSFER CASE ACTIVITY**

7. What were your impressions of the transfer case activity given at the beginning and end of the course?
    - Was your experience with the activity different the second time? *(If so, in what way?)*
    - Do you feel the activity allowed you to demonstrate your learning of ethical decision-making? [Or perhaps your justification of the process?]

**PERSPECTIVE TAKING**

8. Has your ability or tendency to take the perspective of others changed as a result of the course? *[In what way?]*
9. What components of the course helped you take the perspective of others, if any?
    - *Can you provide an example?*
10. To what extent did the perspective-taking activities at the start of the case influence your group's decision in the final case report along each of the cases?

**DISCUSSION, ENGAGEMENT, INTERACTIVITY**

11. What are some of the ways in which you interacted with others during the course (students, instructors, peers, etc.)? [*Prompt: informal or formal, e.g. chat after class, video chat, etc.]*
12. **[If online]:** How might we improve the online experience to allow you to better engage with the class?
13. Can you recall a time in which discussing the course material with someone influenced your understanding or perspective about ethics? *(Please explain)*
14. In what ways did your participation in the <u>classroom discussions</u> -- either in-class or online -- help you to develop your thinking about ethical concepts?
    - If you watched the discussions on video, but did not participate, what do you think you could have gained by being able to participate?
    - Were you comfortable sharing your perspectives and opinions with your classmates? If not, how would you have preferred to share them?
15. Were the <u>group discussions</u> effective for:
    - Learning the case material? *In what ways (or not)*?
    - Changing your thinking about the issues? *Why/how?*
    - Reaching consensus? *Why/how?*
16. To complete the case reports in your group, what process worked best for you? (e.g. Google Docs, VoiceThread, email, etc.) *Why?*

**SCAFFOLDING**

17. How did you feel about using the Pearson OpenClass system?
    - If you've used other online systems in the past, how did this system compare with those?
18. Think about a time you had trouble or questions about the material. How did you typically find the help or support you needed? [Probe: *contact the instructors; navigate the Pearson OpenClass resources; your peers*] Can you give an example?
19. Did you feel you received enough feedback during the course?
    - If yes: What feedback was most useful? (*and when*)?
    - If no: What kind of feedback would you want? (*and when*)?
20. Did the structure of the course guide your learning? In what ways?
    - e.g., case studies, meta-reflection, etc.
21. Which aspect of the course was most challenging to your thinking or reasoning about ethics?
    - *Can you give an example?*
    - How did you respond to these challenges?

**COMMENTS:**

Do you have any other comments you'd like to share about the course, the tools used, the process of discussing and working with your classmates, or your learning experience?

Do you have any questions for me?

Thank you for your time! We appreciate all you've done to help refine this course.

VITA

VITA

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## HIGHER EDUCATION

PhD, Purdue University School of Engineering Education, *2015*

Dissertation Title: A multi-phase exploration of conceptualizations, perceived importance, and the development of empathy within engineering

Dissertation Committee:

1. Johannes Strobel, Co-Chair, Director of Educational Outreach Programs, Engineering Technology & Industrial Distribution, *Texas A&M University*
2. Şenay Purzer, Co-Chair, School of Engineering Education, *Purdue University*
3. Andrew Brightman, School of Biomedical Engineering, *Purdue University*
4. Monica Cardella, School of Engineering Education, *Purdue University*
5. Morgan Hynes, School of Engineering Education, *Purdue University*
6. Joyce Main, School of Engineering Education, *Purdue University*
7. Nadia Kellam, Polytechnic Engineering Program, *Arizona State University*

MSCE Purdue University School of Civil Engineering, *2015*

B.S. Purdue University School of Civil Engineering, Philosophy Minor, *2011*

## PRIMARY RESEARCH INTERESTS

My research is primarily in the domain of engineering education, where my foci include:

1. Exploring the role of **empathy** within design, innovation, and sustainability
2. Synthesizing the influence of societal and individual **worldviews** on decision-making
3. Developing a pedagogical framework to enhance students' **ethical reasoning** skills
4. **Assessing** students' learning in the spaces of design, ethics, and sustainability

## EMPLOYMENT

| | |
|---|---|
| 2013-Present | National Science Foundation Graduate Research Fellow, Purdue |
| 2012-Present | Education Director, Engineers for a Sustainable World |
| 2012-2014 | Teaching Assistant / Faculty Apprentice, Purdue University |
| 2011-2013 | Graduate Research Assistant, Purdue University |
| 2010-2011 | Undergraduate Research Assistant, Purdue University |

## HONORS & AWARDS

*College of Engineering Outstanding Service Award*, Purdue University (April 2014)
*NSF Graduate Research Fellowship*, National Science Foundation (June 2013)
*Summer Undergraduate Research Fellowship*, Purdue University (May 2010)
*SSACI Higher Ed Award Honors*, (2008)
*HK Tony Clark Scholarship,* Purdue University (2008)

## JOURNAL PUBLICATIONS

Hess, J. L., Strobel, J., Pan, R., & Wachter Morris, C. A. (under review). Insights from industry: Analysis of engineers' conceptualizations and perceptions of empathy and care. *Manuscript submitted to the Journal of Engineering Education*.

Hess, J. L., Fila, N. D. (under review). The development and manifestation of empathy within design: Findings from a service-learning course. *Invited submission to a special issue on Visualizing Design Interactions in Educational Settings in CoDesign*.

Dale, A. T., Best, R. E., Hess, J. L., Lennox, E. R., McKhan, D., & Jensen, M. (2014). Connections without command: ESW's service learning approach. *International Journal for Service Learning in Engineering*.

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

Hess, J. L.*, & Strobel, J.* (2013). Indigenous ways of doing: Synthesizing scholarly literature on ethno-engineering. *International Journal of Social Justice, Engineering, and Peace*, *2*(2), 55-80.

## BOOK CHAPTERS

Hess, J. L., Beever, J., Strobel, J., & Brightman, A. (in press). Empathic perspective-taking and ethical decision-making in engineering ethics education. In *Philosophy and Engineering: Exploring Boundaries, Expanding Connections*, ed. Byron Newberry Diane Michelfelder, Qin Zhu. Springer.

Hess, J. L.*, & Fila, N. D.* (in press). Exploring the role of empathy in a service-learning design project. *Invited submission to a book from the DTRS 10 Symposium, Analyzing Design Review Conversations*.

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* Dual and equal first-authorship

## WORKS IN PROGRESS

Hess, J. L., Fila, N. D., Purzer, Ş., & Strobel, J. (in progress). Don't panic!: The relationship between empathic and innovation tendencies among engineering students. *International Journal of Engineering Education*.

Hess, J. L., Strobel, J., Pan, R., & Wachter Morris, C. A. (in progress). Thematic mapping of engineers' perceptions of empathy and care within engineering practice. *Engineering Studies*.

Hess, J. L., Strobel, J., Beever, J., Iliadis, A., Purzer, Ş., & Brightman, A. (in progress). Exploring changes in perspective-taking tendencies using a case-based reasoning approach within an engineering ethics class. *Advances in Engineering Education*.

Hess, J. L., Beever, A., & Brightman, B. (in progress). Comparing ethical reasoning abilities of engineering students using an ethics transfer case methodology. *Science and Engineering Ethics*.

Fila, N. D., Hess, J. L., & Purzer, Ş. (in progress). Innovative behavioral tendencies of engineering students. *Journal of Engineering Education*.

Beever, J., Hess, J. L., & Brightman, B. (in progress). Deepwater horizon oil spill: An environmental engineering ethical case study. *Science and Engineering Ethics*.

## MANUSCRIPTS PUBLISHED IN CONFERENCE PROCEEDINGS

Hess, J. L., Fila, N. D., Strobel, J. & Purzer, S. (2015). *Exploring the relationship between empathy and innovation amongst engineering students*. Paper presented at the American Society of Engineering Education Annual Conference, Seattle.

Hess, J. L., Brownell, S., House, R. A., & Dale, A. T. (2015). *Development and application of the Sustainability Skills and Dispositions Scale to the Wicked Problems in Sustainability Initiative*. Paper presented at the American Society of Engineering Education Annual Conference, Seattle, WA.

Fila, N. D., Hess, J. L., & Purzer, S. (2015). *A dialectic data integration approach for mixed methods survey validation*. Paper presented at the American Society of Engineering Education Annual Conference, Seattle, WA.

Fila, N. D., Hess, J. L., & Purzer, S. (2015). *Challenges to and development of innovation discovery behaviors among engineering students*. Paper presented at the American Society of Engineering Education Annual Conference, Seattle, WA.

Dale, A. T., House, R. A., Brownell, S. E., Best, R. E., & Hess, J. L. (2015). *Scaling support for teaching sustainability: Reflections, barriers and opportunities*. Paper presented at the 7th International Conference on Engineering Education for Sustainable Development, Vancouver, Canada.

**MANUSCRIPTS PUBLISHED IN CONFERENCE PROCEEDINGS (CONT.)**

Hess, J. L.*, Fila, N. D.* (2014). *Exploring the role of empathy in a service-learning design project*. Paper presented at the 10th Design Thinking Research Symposium, Purdue University, West Lafayette, IN.

Hess, J. L., Beever, J., Iliadis, A., Kisselburgh, L. G., Zoltowski, C. B., Krane, M. J. M., & Brightman, A. O. (2014). *An ethics transfer case assessment tool for measuring ethical reasoning abilities of engineering students using reflexive principlism approach*. Paper presented at the IEEE Frontiers in Education Annual Conference, Madrid, Spain.

Jaycox, H., Hess, J. L., Zoltowski, C. B., & Brightman, A. O. (2014). *Developing novel practices of somatic learning to enhance empathic perspective-taking for ethical reasoning and engineering design*. Paper presented at the IEEE Frontiers in Education Annual Conference, Madrid, Spain.

Fila, N. D., Hess, J. L., Hira, A., Joslyn, C., Tolbert, N., & Hynes, M. (2014). *Engineering for, with, and as people*. Paper presented at the IEEE Frontiers in Education Annual Conference, Madrid, Spain: IEEE.

Dale, A. T., Hess, J. L., Best, R. E., Lennox, E. (2014). *Beyond professional development: The value proposition of multi-disciplinary networks for creating global engineers*. Paper presented at Engineering Leaders for Grand Challenges, Doha, Qatar.

Hess, J. L., Brownell, S., & Dale, A. (2014). *The wicked problems in sustainable engineering (WPSE) initiative: Pilot results of a cross-institutional project-based course offering*. Paper presented at the American Society of Engineering Education Annual Conference, Indianapolis, IN.

Hess, J. L., Strobel, J., Pan, R., & Wachter Morris, C. W. (2014). *Practicing engineers' perceptions of empathy and care: Findings from a 37-Item survey*. Paper presented at the American Society of Engineering Education Annual Conference, Indianapolis, IN.

Kisselburgh, L., Zoltowski, C., Beever, J., Hess, J. L., Iliadis, A., Krane, M., & Brightman, A. (2014). *Effectively engaging engineers in ethical reasoning about emerging technologies: A cyber-enabled framework of scaffolded, integrated, and reflexive analysis of cases*. Paper presented at the American Society of Engineering Education Annual Conference, Indianapolis, IN.

* Dual and equal first authorship

## MANUSCRIPTS PUBLISHED IN CONFERENCE PROCEEDINGS (CONT.)

Hess, J. L., & Strobel, J. (2013). *Sustainability and the engineering worldview*. Paper presented at the IEEE Frontiers in Education Annual Conference, Oklahoma City, OK.

Kisselburgh, L., Zoltowski, C., Beever, J., Hess, J. L., Krane, M., & Brightman, A. (2013). *Using scaffolded, integrated, and reflexive analysis (SIRA) of cases in a cyber-enabled learning infrastructure to develop moral reasoning in engineering students*. Paper presented at the IEEE Frontiers in Education Annual Conference, Oklahoma City, OK.

Hess, J, L. (2013). *Global portrayels of engineering ethics education*. Paper presented at American Society of Engineering Education National Conference, Atlanta, GA.

Hess, J. L., Sprowl, J. E., Pan, R., Dyehouse, M., Wachter Morris, C. A., & Strobel, J. (2012). *Empathy and caring as conceptualized inside and outside of engineering: Extensive literature review and faculty focus group analyses*. Paper presented at ASEE Annual Conference & Exposition, San Antonio, TX.

## PRESENTATIONS OUTSIDE OF PURDUE UNIVERSITY

Hess, J. L. (2015, April). *Teaching sustainability*. Facilitated presentation and discussion at the Engineers for a Sustainable World Annual Conference, Rochester, NY.

Hess, J. L. (2015, January). *Empathy and ethical decision-making: Investigating changes in engineering students' empathic perspective-taking tendencies*. Invited presentation at Virginia Tech, Blacksburg, VA.

Hess, J. L., Beever, J., Brightman, B., Iliadis, A., Zoltowski, C., & Kisselburgh, K. (2014, October). *A novel engineering ethics case study designed in the SIRA framework using reflexive principlism to engage students and teach ethical reasoning*. Presentation at the Society for Ethics Across the Curriculum's 16th Annual Conference, Scottsdale, AZ.

Dale, A. & Hess, J. L. (2014, June). *The wicked problems in sustainability initiative: Teaching complex topics through shared resources*. Presentation at Seventh Symposium on Engineering and Liberal Education, Schenectady, NY.

Hess, J. L., Strobel, J., Beever, J., & Brightman, A. (2014, May). *Empathy and ethical decision-making in engineering ethics education*. Presentation at 2014 Forum on Philosophy, Engineering and Technology, Blacksburg, VA.

Hess, J. L., & Dale, A. (2014, April). *Wicked problems in sustainability initiative*. Presentation through Engineers for a Sustainable World Annual Conference, Evanston, IL.

## PRESENTATIONS OUTSIDE OF PURDUE UNIVERSITY (CONT.)

Lennox, E. & Hess, J. L. (2014, April). *Human-Centered Design*. Educational Webinar hosted by Engineers for a Sustainable World.

Beever, J., Brightman, A., Hess, J. L., Hiles, M., Iliadis, A., Kisselburgh, K., Krane, M., & Zoltowski, C. (2013, September). *S.I.R.A. Modules for Effectively Engaging Engineers in Moral Reasoning*. Ethics and Education in Science and Engineering Program. National Science Foundation, Washington D.C.

Dale, A., & Hess, J. L.. (2013, June). *Wicked Problems in sustainabile engineering (WPSE)*. Poster presented at the ASEE National Conference, Atlanta, GA.

Lennox, E., Dale, Al, & Hess, J. L. (2013, June). *Engineers for a Sustainable World: Interdisciplinary education through student-driven sustainability projects*. Poster presented at Union College Sixth Symposium on Engineering and Liberal Education, Schenectady, NY.

Beever, J., Brightman, A., Hess, J. L., Hiles, M., Kisselburgh, L., Krane, M., & Zoltowski, C. (2013, May). *Reflexive principlism for biomedical engineering ethics education*. Poster presented to the Values in Medicine, Science, and Technology conference, UT Dallas, Texas.

Hess, J. L., Lee, N., & Strobel, J. (2010, November). *Indigenous engineering and the intersection of indigenous feminism*. Presentation at National Women's Studies Association Annual Conference, Denver, CO.

## PRESENTATIONS AT PURDUE UNIVERSITY

Hess, J. L., & Brightman, A. (2013, October). *Using scaffolded, interactive, and reflective analysis of cases in a cyber-enabled learning infrastructure to develop moral reasoning and empathy in engineering ethics education*. Presentation at Purdue University School of Engineering Education Research Seminar Series, West Lafayette, IN.

Hess, J. L., & Strobel, J. (2013, January). *Indigenous engineering: Learning from sustainable practices*. Presentation at Purdue University School of Engineering Education Research Seminar Series, West Lafayette, IN.

Strobel, J., & Hess, J. L. (2013, January). *Indigenous engineering: Learning from sustainable practices*. Presentation at Purdue University ABE-GSA Professional Development Seminar, West Lafayette, IN.

Hess, J. L., Sprowl, J., Pan, R. C., Wachter Morris, C., & Strobel, J. (2012, March). *Understanding the role of empathy and care within engineering*. Poster presented at Anual Graduate Student Educational Research Symposium, Purdue University, West Lafayette, IN.

## PRESENTATIONS AT PURDUE UNIVERSITY (CONT.)

Hess, J. L., Pan, R. C., Klingler, L., Wachter Morris, C., Dyehouse, M., Weber, N., et al. (2011, November). *Empathy & care: Attributes underlying sustainable engineering practice?* Poster presented at Ecological Sciences and Engineering Annual Symposium: "Solutions for 7", Purdue University, West Lafayette, IN.

Weber, N., Dyehouse, M., Wachter Morris, C., Klingler, L., Pan, R., Stephens, M., Hess, J. L., & Strobel, J. (2011, October). *Engineering as a caring and empathetic discipline: Conceptualizations and comparisons*. Poster presented at Engineer of 2020 Annual Workshop, Purdue University, West Lafayette, IN.

## WORKSHOPS ORGANIZED

Beever, J., Brightman, A., Hess, J. L., & Zoltowski, C. (2015, June). *New paradigms and tools for engineering ethics education*. Workshop at the American Society for Engineering Education Annual Conference, Seattle, WA.

Hess, J. L., Dale, A. T. (2015, April). *Wicked Problems in Sustainability Initiative (WPSI) Summit II*. Workshop at Engineers for a Sustainable World National Conference, Rochester Institute of Technology, Rochester, NY.

Hess, J. L., Dale, A. T. (2014, April). *Wicked Problems in Sustainability Initiative (WPSI) Summit*. Workshop at Engineers for a Sustainable World National Conference, Northwestern University, Evanston, IL.

Hess, J. L. (2013, November). *Instructional design for K-12 education and outreach*. Workshop at Engineers for a Sustainable World Regional Conference, Pittsburgh University.

## TEACHING EXPERIENCE

**BME595: Global Experience of Medical Device Design**, Purdue, *May 2014 & 2015*

- Faculty Apprentice for a 2-week study abroad course offering (led by Dr. Andrew Brightman and Holly Jaycox) situated in Ireland that focused on using an empathic design process to develop assistive technologies for people with cardiovascular disease
- Developed course activities in relation to the EPICS design process, empathic design, engineering ethics, somatic awareness practices, and engineering worldviews
- Facilitated assessment components of course, including design reviews, peer evaluations, course evaluations, and providing formative feedback on students' written assignments

## TEACHING EXPERIENCE (CONT.)

**ENGR 1060/2060: Social Entrepreneurship**, Pittsburgh, *Fall 2013 & 2014*
**CMDS-333: Wicked Problems in Sustainability**, RIT, *Fall 2013 & 2014*
**RH-330: Technical and Professional Communication**, Rose-Hulman, *Fall 2014*

- External advisor for 3 separate courses offered at the University of Pittsburgh led by Alexander Dale, Rochester Institute of Technology led by Sarah Brownell, and Rose-Hulman Institute of Technology led by Richard A. House, respectively per above order

  *Note:* Each of these courses are part of the Wicked Problems in Sustainability Initiative through Engineers for a Sustainable World
- Developed and implemented an assessment framework which included (a) using Denny Davis's IDEALs framework for design reviews, (b) the development of a pre-post survey measuring students attainment of learning objectives, and (c) using concept maps to develop and assess students' meta-cognitive awareness of sustainability
- Worked alongside instructors throughout course offerings, providing feedback to instructors on assessment techniques, and providing feedback to students on submitted preliminary, interim, and final design review submissions

**BME595: Solving Ethical Problems in Engineering**, Purdue University, *Spring 2013, Summer 2013, Spring 2014, & Summer 2014*

- Teaching Assistant for a hybrid course offering (with both in-class and on-line students) led by Dr. Andrew Brightman
- Developed and implemented pedagogical techniques to scaffold students' understanding of principlism of ethical issues and promote reflexivity in their reasoning processes
- Developed an assessment framework to measure students' changes in empathic perspective taking and ability to apply reflexive principlism to a transfer case
- Managed content delivery and discussion forums using GlobalHub (2013) and Pearson OpenClass (2014) as content management systems

## RESEARCH EXPERIENCE

Graduate Research Fellow funded through the National Science Foundation's Graduate Research Fellowship Program, June 2012-current.

Graduate Research Assistant for P.I. Dr. Johannes Strobel on the project *Creating a Concerned Engineering in a Changing Environment* funded by the Engineer of 2020 Internal SEED Grant through the College of Engineering at Purdue University, May 2011-2013

## RESEARCH EXPERIENCE (CONT.)

Graduate Research Assistant for P.I. Dr. Andrew Brightman on the project *SIRA Modules for Effectively Engaging Engineers in Ethical Reasoning about Emerging Technologies* funded by NSF EESE Grant, Purdue University, August 2012-June 2013

Undergraduate Research Assistant for Dr. Johannes Strobel on the project *A different engineering: Indigenous Knowledge Structures, Technologies and Sustainability Design*, Purdue University, May 2010- May 2011

## SERVICE EXPERIENCE

**Purdue University**

- EPICS Design Reviewer, *2014*
- First-Year Engineering Design Reviewer, *2013, 2014*
- Purdue University School of Engineering Education Faculty Search Committee, *2013*
- Engineering Education Graduate Student Association (ENEGSA), *2011-2013*
  - President for 2012-2013 Academic Year
  - Communications committee chair for 2011-2012 Academic Year
- India Global Design Team (GDT) Participant and Team Leader, *2011-2012*
- Big Brothers Big Sisters Purdue Chapter (BBBS), *2007-2009*
  - Leader of Cool Kids After School program for 2008-2009 Academic year

**Engineers for a Sustainable World**

- National Team Education Director, *2013-present*
  - Developed and led educational webinars and skills webinar series
  - Developed and oversaw project initiatives, including the multiple-campus initiative, Wicked Problems in Sustainability
  - Led a 4-week short-course on Wicked Problems in Sustainability, August 2014
- National Team Director of Technology and Events for 2012-2013 Academic Year
  - Maintained and reformatted website using Drupal
  - Helped organize and run Fall 2013 regional conferences and the 2012 annual national conference at San Diego State University
- Purdue Chapter Graduate Advisor for 2012-2013 Academic Year
- Student Chapter Member, 2010-2011

**American Society of Civil Engineers**

- Committee on Sustainability, Formal Education Subcommittee Member, *2015*

## SERVICE EXPERIENCE (CONT.)

**Journal Manuscript Reviewing and Editing**

- Engineering Studies Assistant Editor, *2012-present*
- International Journal of Engineering, Social Justice, and Peace Manuscript Reviewer, *2014-present*
- Journal of Professional Issues in Engineering Education and Practice Manuscript Reviewer, *2014-present*
- Science Education Manuscript Reviewer, *2014-present*
- Journal of Pre-College Engineering Education Research Manuscript Reviewer, *2013*

**Conference Divisions Volunteering, Reviewing, and Moderating**

- American Society of Engineering Education LEES Divison Webmaster, *2014-present*
- Society for Ethics Across the Curriculum Annual Conference Session Moderator, *2014*
- Design Thinking Research Symposium Manuscript Reviewer, *2014*
- Frontiers in Education Ethics Division Paper Reviewer, *2013*
- American Society of Engineering Education LEES Divison Paper Reviewer, *2012-2015*
- ASEE annual conference Ethics & LEES Divisions Session Moderator, *2012, 2013*

## GRANTS

*College of Enginering Travel Grant*. (2014). Purdue University College of Engineering. $500 awarded.

*Graduate Research Fellowship*. (2013). National Science Foundation. $96,000 awarded.

*Study Abroad and International Learning Grant*. (2013). Purdue University International Programs and Global Engineering Programme. $8000 awarded.

*College of Engineering Request for Proposals*. (2012). Purdue University COE. $1400 awarded to Engineering Education Graduate Student Association.

*India Global Design Team*. (2012). Purdue University Student Grant Program for Community Service/Service Learning. $1500 awarded.

*University Incentive Grant*. (2008-2011). Purdue University. $11,500 awarded.

*Summer Undergraduate Research Fellowship*. (2010). Purdue University. $4200 awarded.

*National Smart Grant*. (2009-2010). Purdue University. $4000 awarded.

## ENGINEERING PRACTICE

**Opus West Engineering Professional Practice Program (Co-op),** ***January-June 2009***

- Assisted in project management of a nine-story shell office structure in Tempe, AZ
- Managed and coordinated scheduling, the final punch list, and change orders
- Compiled safety documentation and conducted safety orientation meetings
- Fabricated final clean bid package, submitted and evaluated subcontractors' submissions and supervised the implementation of the final clean

## INTERNATIONAL EXPERIENCE

**Ireland Design Course Faculty Apprenticeship**, *2014, 2015*

- Led a study abroad course offering through Purdue University
- Mentored students in their projects that sought to help patients with cardiovascular disease, working alongside project partners – Croi House in Galway and Enable Ireland in Dublin

**India Global Design Team**, *2012*

- Developed fluoride treatment prototype for farms near Bhubaneswar, Odisha, India
- Visited local farms and inhabitants to collect water samples for testing
- Tested collected water samples using activated alumina prototype

**London Facilities and Infrastructure Engineering Study Abroad**, *2010*

- Analyzed engineering and construction issues linked to the facilities and infrastructure being developed for the 2012 Olympics in London, United Kingdom
- Met with engineers working on large scale infrastructure projects such as the Crossrail and the London Tideway Tunnels

## PROFESSIONAL MEMBERSHIPS

| | |
|---|---|
| American Society of Civil Engineering (ASCE): | *2014- present* |
| American Society for Engineering Education (ASEE): | *2011-present* |
| Chi Epsilon Civil Engineering Honors Fraternity (XE): | *2010-present* |
| Engineers for a Sustainable World (ESW): | *2009-present* |

## SOFTWARE EXPERIENCE

| | |
|---|---|
| *Autodesk Software*: | AutoCAD, Autodesk Inventor |
| *Computational Programs:* | MathCAD, Matlab |
| *Energy Analysis Software*: | RetScreen, SimaPro |
| *Mapping and Modeling Tools*: | ArcGIS, HEC-RAS, Hydrain, Pipe2008 |
| *Qualitative Data Analysis:* | ATLAS.ti, Max QDA, QDA Miner |
| *Project Management:* | MS Project, Primavera P6, TRIRIGA |
| *Simulation Software:* | AnyLogic, EZStrobe |
| *Statistical Packages:* | Limdep/NLogit, SPSS |