

Engineering to Care: Exploring Engineering in Humanitarian and
Social Justice Contexts through a Lens of Care Ethics

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Abstract*

Engineering to Care: Exploring Engineering in Humanitarian and
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Engineering and technology have changed the lives of many on this planet. However, technical solutions are not the value-neutral panaceas we might imagine them to be. If we engineers are unaware of the values driving our efforts, we are unlikely to create lasting solutions to the problems we hope to address. In fact, engineers may have inadvertently helped create many of the problems that plague the world today, such as those associated with environmental pollution and anthropogenic climate change. Without examining our values and perhaps even adopting new ones, we may create as many problems as we solve for society.

In this dissertation, I contribute to the thought and dialogue needed to create change in the value system of engineering by exploring an ethical framework that has received little attention in

* Portions of this abstract are adapted from Campbell & Wilson (2016).

the engineering-related literature to date. Care ethics, also known as the ethics of care, is a normative ethical theory emphasizing care, compassion and context rather than impartiality and universal standards. As part of a pluralistic approach to ethics, it contributes important perspectives that are missed by other theories. By actively striving for equity rather than implicitly presuming equality, care ethics helps us to account for real-world differences in power and autonomy, and to give additional consideration to the vulnerable or disadvantaged.

This work was guided by three overarching questions: one conceptual, one empirical, and one directed at implications. The conceptual question read “How might care ethics manifest in engineering?” In addressing it, the key outcomes were the identification of a suitable care ethics framework for use in the empirical work, and the demonstration of its applicability to engineering, especially in humanitarian and/or social justice contexts. The empirical question was “In terms of care ethics, how do students in traditional engineering programs respond to problems of humanitarian or social justice nature?” and was broken down into three, more specific sub-questions, each directed at a different engineering context and associated data set. The implications question read “What are the implications of the above (e.g., on course design, curricular change, educational policy, engineering practice)?” and was explored for each of the three sub-questions.

The empirical research was conducted under an interpretive conceptual framework using qualitative methods of thematic analysis and comparative case study analysis; however, a more innovative approach to the analysis was also taken, one that involved using the empirical data to iteratively co-develop operationalizations of specific elements of the adopted care ethics framework, namely Attentiveness and Responsibility. Thus, the concepts from care ethics theory both constrained and were clarified by the findings over the course of analysis and writing. Consequently, the outcomes of the empirical analyses were comprised of multiple components,

including (a) findings that were descriptive and ostensibly “close to the data”, (b) findings that were more interpretive, based on an evolving understanding of care ethics and how it applies in these engineering contexts, and (c) practical operationalizations of care-ethics that are useful for teaching, learning, assessment, and further research.

An example of a descriptive outcome from the first data set ($n = 73$) was that most engineering students reported their knowledge of Hurricane Katrina as having affected their responses to a conceptually related design task (performed nine months after the hurricane); however, a large minority of the students said it had no effect. When it was a factor, students said it helped them consider people, the natural environment, and aspects of design approaches in addition to technical details. From an interpretive perspective, this suggests that doing design in a context that has humanitarian and/or social justice dimensions may result in better, more care-ethically attentive engineering work, but only if the necessary connections between the context and the task at hand are made. Educators will need to help students learn to make these connections.

An example finding from the second data set ($n = 30$) was that most engineering students associated engineers with responsibility for the problem of “backyard” e-waste recycling in the “developing world” in some way, but some students seemed inclined to limit or deflect that responsibility toward others. This can be interpreted as a strength in some cases, where it demonstrates a realistic sense of the complexity of the problem and the many stakeholders that must necessarily be involved in its solution. However, it can also be interpreted as a weakness in other cases, where it may suggest notions of engineers as lacking a sense of agency to affect change in an area they clearly have influence. Key implications are that educators should raise awareness of the problems of backyard e-waste recycling in general and help students learn to consider a broader range of stakeholders so that important solution approaches are not missed.

The third data set—a comparative case-study of two group design project reports—illustrated contrasting approaches to design in the developing world context. One group demonstrated care-ethical awareness, sensitivity, and appreciation of the expressed needs of the end user, while the other group adopted a more paternalistic approach suggestive of technological imperialism. The findings also revealed differences in the way responsibility was discussed, which may be indicative of varying levels of commitment and/or notions of agency. A key curricular implication is for educators to bring user-centered and participatory design approaches into more engineering disciplines, such as electrical engineering and civil engineering.

An example of a useful operationalization of care-ethics that came out of the work was the idea to assess aspects of care-ethical attentiveness and responsibility with different measures of stakeholder identification. For example, to assess the care-ethical quality of one's design considerations, one might look for indications of awareness of disadvantaged (i.e., vulnerable, powerless, and/or underprivileged) stakeholders and their needs.

This work has provided some necessary first steps toward understanding the concepts and constructs needed for further investigations into the neglected area of care ethics in engineering. The simultaneously top-down and bottom-up approach used in this research has both facilitated a deeper understanding of the ethical responsibilities of engineers and provided a baseline for understanding the ethical thinking of engineering students, who are the next generation of engineers. This work has also shown how care ethics might be applied to engineering and suggested ways engineering might need to change to become more open to and consistent with the ideals of care ethics.

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Acknowledgments

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[†] The Bahá'í Faith is an independent world religion that can be most succinctly summarized by the ideal of unity. It's teachings call for the abolition of all forms of prejudice, explicitly embrace the equality of women and men, recognize the Divine origins of previous religions (for example, Buddhism, Christianity, Hinduism, Islam, Judaism, and Zoroastrianism), and view science and religion as necessary, complementary means through which humankind strives to understand Truth. For more information, see www.bahai.org and/or find the website for the Baha'is in a particular country or language at <http://www.bahai.org/national-communities>

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Chapter 1. Introduction¹

Engineering and technology have changed the lives of many people on this planet. However, technical solutions are not the value-neutral panaceas we might imagine them to be (e.g., see Latour 1992; Friedman 1996; Franssen et al. 2013; Pesch 2015). If we as engineers do not know, understand, articulate, or discuss the values that are driving our efforts, then we are far less likely to create lasting solutions to the problems we hope to address. In fact, engineers may have inadvertently helped to create many of the problems that plague the world today, such as those associated with environmental pollution and anthropogenic climate change. Without examining our values and perhaps even adopting new ones, we may continue creating as many new problems as we solve for society. However, the changes that are necessary for the engineering profession to seriously reflect on its values and adopt new ones will not happen easily.

In this dissertation, I contribute to the thought and dialogue needed to create change in the value system of engineering by exploring an ethical framework that has received little attention in the engineering-related literature to date. Care ethics, a.k.a., ethics of care is a normative ethical theory emphasizing care, compassion and context rather than impartiality and universal standards. Compared to conventional ethical frameworks of consequentialism (e.g., utilitarianism) and deontology (e.g., duty- or rule-based ethics), care ethics provides a shift in moral perspective from asking “what is just?” and instead asks “how to respond?” (Gilligan 1995). Care ethics addresses missing dimensions in conventional ethical thinking by accounting for real-world differences in power and dependence, and by giving additional consideration to the vulnerable or disadvantaged (e.g., it targets equity rather than presuming equality). While care ethics might not be the only ethical framework needed in a given situation, to neglect the considerations that care ethics provides in favor of other frameworks opens the door to oppression and injustice. As Tronto (1993, p. 147) wrote: “a moral theory that can recognize and identify these issues [e.g., privilege, paternalism, parochialism] is preferable to a moral theory that, because it presumes that all people are equal, is unable even to recognize them.”

¹ Portions of this introduction are adapted from Campbell & Wilson (2016).

In the remainder of this chapter, I discuss the relevance of the work to current national priorities in engineering education and to accreditation internationally. Then, I review some related literature before previewing the contributions of the work. I conclude the chapter with a description of the study design. The core work of the dissertation begins in the second chapter by exploring engineering conceptually through a care-ethics lens. I then add an empirical dimension in the next three chapters with engineering student perspectives from three different engineering contexts. Each of these contexts, described below, involve problems of a humanitarian and/or social justice nature in which caring qualities can reasonably be expected to be important. I then conclude the dissertation with a chapter that summarizes and synthesizes the work.

The first engineering context is natural disaster prevention. In Chapter 3, I look at the ways in which students in 2006 said their knowledge of Hurricane Katrina (and its impact on New Orleans) influenced their design thinking on a river retaining wall design task. While I certainly believe engineers should learn from engineering failures and be motivated by them to improve their work, the purpose of this chapter is to explore, in terms of care ethics, how students themselves talked about the influence of their knowledge of Hurricane Katrina on their design thinking. Note that Hurricane Katrina was both a natural disaster and a humanitarian disaster with important social justice implications, and was thus a context in which caring attitudes could reasonably be expected.

The second engineering context is “back-yard” electronic waste recycling. In Chapter 4, I explore how students wrote about engineers’ responsibilities for the human health and environmental impacts of “backyard” electronic waste (e-waste) recycling that presently occurs in many industrializing countries, such as India and China (Sepúlveda et al. 2010). While I believe that engineers have ethical responsibilities to address the e-waste problem (and that there are actions engineers can and should take, both inside and outside the traditional purview of engineering), the purpose of this chapter is not to argue this position directly, but to explore, in terms of care ethics, what a diverse sample of students in a traditional engineering course thought about this problem. The e-waste problem serves as another instance of a humanitarian or social justice issue for which care ethics is particularly well-suited.

The third context is rural electrification in the “developing world.” In Chapter 5, I look at the ways in which student teams approached preliminary designs for expanding a large-scale electric power system from an industrialized into non-industrialized region. While I believe there are more and less ethical approaches to such forms of international development, the purpose of this chapter is to explore, in terms of care ethics, the spectrum of student responses found in two contrasting case studies and use them to better understand care ethics in this, and perhaps other, engineering contexts. This design for the “developing world” context provides another space where caring attitudes could reasonably be expected.

This work involves qualitative exploration of engineering student statements and writing, and takes an uncommon approach to engineering ethics by using this empirical analysis to foster conceptual/philosophical exploration. This approach enhances critical understanding of the next generation of engineers who will soon be making decisions for the engineering field. Furthermore, through the introduction and explication of a care ethics framework as applied to engineering, the work provides reflection on the purpose and responsibilities of the field of engineering, with implications on educational policy and the practice of engineering. These outcomes of the work can be used to inform engineering course design, such as by incorporating new ethics and social justice issues into traditional engineering programs or creating humanitarian engineering (H.E.) programs. The work can also suggest broader curricular changes beyond the existing terms of mainstream discussions on curricular content and pedagogy.

1.1. RELEVANCE OF THIS RESEARCH²

This work has relevance to current priorities in engineering education as recognized by national policy makers. For example, in the Engineer of 2020, the National Academy of Engineering (NAE) wrote of aspiring “to a future where engineers are prepared ... to ethically assist the world in creating a balance in the standard of living for developing and developed countries alike” (NAE 2004, p. 51). They also noted the importance of educating engineers who are “ethically grounded” (NAE 2004, p. 5), though they left the task of articulating specifically what that might mean to

² This section is adapted from Campbell & Wilson (2011).

others. My work speaks directly to both of these points by identifying a suitable ethical framework (care ethics) and exploring it in relevant contexts.

Additionally, many engineering programs around the globe have accreditation requirements they are encouraged, if not somehow required, to meet. Probably the most widely known engineering and technology accreditation organization is ABET (formerly known as the Accreditation Board for Engineering and Technology) which advocates its Accreditation Criteria, Policies & Procedures for a variety of engineering and science programs internationally. Several of ABET's Criteria 3 Program Outcomes are particularly challenging to cover in engineering programs because they are complex and difficult to incorporate in mainstream engineering courses. This is especially true of those outcomes that require students to attain:³

“(f) an understanding of professional and ethical responsibility”

and

“(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context”

as well as the italicized design constraints indicated in

“(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, *environmental*, *social*, *political*, *ethical*, health and safety, manufacturability, and *sustainability*”

Similar criteria for ethics and broad contextual understanding are also found in the accreditation requirements of the European Network for Accreditation of Engineering Education (ENEAA), which promotes the EUR-ACE Framework Standards,⁴ and in the International Engineering Alliance's (IEA) Graduate Attributes and Professional Competencies document, which summarizes desired knowledge and attribute profiles from three international accreditation agreements (the Washington Accord, the Sydney Accord, and the Dublin Accord).⁵

³ ABET Criteria for Accrediting Engineering Programs, 2015-2016, General Criteria 3. Student Outcomes. <http://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2015-2016/>

⁴ See ENEAA's EUR-ACE Framework Standards, Section 2.3.1. Programme Outcomes for Bachelor Degree Programmes. <http://www.enaee.eu/wp-content/uploads/2015/04/EUR-ACE-Framework-Standards-and-Guidelines-Mar-2015.pdf>

⁵ See IEA's Graduate Attributes and Professional Competencies, Section 5. Accord programme profiles. <http://www.ieagreements.org/IEA-Grad-Attr-Prof-Competencies.pdf>

My work speaks directly to the above outcomes by exploring an ethical framework (care ethics) that even helps define the meaning of “ethical responsibility” in engineering, and it does so in contexts that encourage, if not require, breadth of understanding. These accreditation criteria can all be addressed (utilizing the synergy between them—see Section 1.2.1 below) by incorporating care ethics in engineering, such as through topics related to humanitarian engineering or engineering and social justice. This can occur in a variety of learning environments, including service learning, student-led organizations (e.g., Engineers Without Borders), and even in the classroom (as exemplified in this dissertation) via such means as case studies, design problems, and writing assignments.

1.2. REVIEW OF RELATED LITERATURE⁶

In this subsection, I briefly review a broad collection of related literature, including that illustrating such themes as the synergy between ethics and the societal impacts of engineering, service learning & humanitarian engineering, emotion & empathy in engineering, ethical theories in engineering, and finally care ethics. More focused literature reviews also appear where appropriate in some of the subsequent chapters, (e.g., see Section 2.2 for more on care ethics in general and Section 4.1 for information on a particular element of care ethics: Responsibility).

1.2.1. SYNERGY BETWEEN ETHICS AND SOCIETAL IMPACTS OF ENGINEERING

Some engineering educators have noticed the connections between ethics (at least as conventionally conceived) and the broader societal impacts of engineering. For example, Herkert (2000) has explicitly highlighted the natural link between ABET “(f)” and “(h)” and very clearly advocates teaching them together because the broader context provided by coverage of “(h)” supports a broader macro-ethical coverage of “(f).” Devon (1999) has a similar perspective, though not in the context or language of ABET, but via similar ideas in industry. Specifically, he pointed out the limitations of using moral dilemmas posed to the individual when teaching engineering

⁶ Portions of this section are adapted from Campbell & Wilson (2011), Campbell, Yasuhara, & Wilson (2015), and Campbell & Wilson (2016).

ethics, and suggested instead using a group-based ethical decision making process that reflects the consensus approach to technology development that actually occurs in industry: an approach that considers social relationships such as those among the engineering design group, the company, the client, and the government.

1.2.2. SERVICE LEARNING AND HUMANITARIAN ENGINEERING

Several engineering ethicists (Pritchard 1998; Haws 2001; Tsang & Pritchard 2000) have described the likelihood of effective ethics learning opportunities inherent in engineering service learning, in which programs of humanitarian engineering are often manifest. H.E. itself has been recognized by several engineering educators as having valuable potential for creating a new and meaningful approach to engineering ethics education. Lucena et al. (2007) even go so far as to state that the focus of engineering ethics on individual and social responsibilities in the industrialized world has overlooked humanitarian engineering as “an important dimension of engineering practice that deserves clearer ethical articulation and curriculum development.”

A compelling case for the integration of H.E. topics into technical communication courses for engineers has been made by Berndt & Paterson (2009), who suggest that “incorporating humanitarian [case studies] into technical communication courses would promote higher levels of learning, student engagement, and the global citizenship that will be requisite for all engineers in the twenty-first century.” Passino (2009) shows how engineering ethics and professionalism can be augmented by H.E. through its spirit of volunteerism, which, while prevalent in law and medicine, needs to be encouraged in engineering. Passino also provided sample H.E. course materials in the form of a classroom project in which students design a personal electricity generation system, and he has created a collection of low cost engineering laboratories intended for educational use in resource-constrained environments, with the aim of encouraging volunteerism and teaching ethics alongside technical concepts like control systems feedback, disturbance rejection, and nonlinear control.

1.2.3. EMOTION AND EMPATHY IN ENGINEERING

Roeser (2010) provided a valuable starting point for the integration of "emotion" into engineering design, seeking to help change the view of engineers as being cold, detached, rational, analytical problem solvers. In this dissertation, I suggest that topics of a humanitarian and/or social justice nature provide a natural way of introducing empathy and emotion, appropriately applied, into engineering education. While such concerns (and the resulting political, social or cultural design constraints they often create) may often appear silly or irrational to the engineering student, they are very important none-the-less, often making or breaking engineering projects.

The associated notion of empathy is also receiving attention in engineering education research, such as by Strobel et al. (2011, 2013), who looked at how notions of empathy and care are conceptualized in engineering and other disciplines and how it is incorporated into the curriculum; Hess et al. (2012), who looked at how engineering and non-engineering faculty conceptualize empathy and care and how they perceive them to intersect with engineering; Walther, Miller, & Kellam (2012), who explored the role of empathy in engineering communication; and Strobel et al. (2013), who looked at how notions of empathy and care are reflected in the engineering literature and perceived by engineering faculty and practicing engineers in engineering contexts.

1.2.4. ETHICAL THEORIES IN ENGINEERING

Looking at the history of ethical theories, we can see that the forms of ethics prevalent in today's society—particularly in the areas of law and risk management from which engineering ethics often borrows—are based on the philosophies of utilitarianism and Kantian deontology (Pantazidou & Nair 1999). These are views of morality that have come under much criticism in moral philosophy since the 1950's, and are now also being challenged not only by care ethics, but by a renaissance of virtue ethics (Gardiner 2005; Peterson & Seligman 2004). Virtue ethics was historically championed by such philosophers as Plato, Aristotle and later by Thomas Aquinas. Discussions of what virtue ethics might look like in engineering ethics education are found in Harris (2008), Martin & Schinzinger (2006), Seebauer & Barry (2001), Jordan (2006), and Moriarty (2008).

Moriarty's (2008) work is particularly oriented toward caring, but it does not associate with the literature on care ethics specifically (see next subsection). In agreement with Moriarty, I believe notions of care should be cultivated and encouraged in all engineering students to help them in becoming responsible professional engineers. Furthermore, focusing on care ethics need not exclude more traditional ethical approaches that underlie most engineering ethics instruction today: indeed they can and should be complementary (see Held 2007). Virtue ethics, for example, is a framework in which both care ethics and other forms of ethics can find expression, and through which care ethics could become an explicit aspect of engineering ethics instruction, provided this is done carefully to avoid obscuring key aspects of care ethics, such as its pragmatic nature and ability to spotlight differences of power and privilege (see Sander-Staudt 2006).

Furthermore, virtue ethics is garnering empirical support from a new branch of psychology known as positive psychology. Positive psychology has grown out of the theoretical work of humanistic psychologist Abraham Maslow who sought to study the exemplary rather than the sick or dysfunctional (Peterson & Seligman 2004). Some conceptual work has been done to articulate a formal "positive ethics" (Handlesman et al. 2002; Handlesman et al. 2009), which appears to be very pluralistic and widely applicable. Ideas of positive ethics are starting to find their way into discourse on engineering ethics: see for example Michael Pritchard's promotion of "moral exemplars" (Pritchard 1998). Humanitarian engineering and social justice contexts naturally provide an arena for focusing on the positive, not only through the use of such moral exemplars as engineer Fredrick Cuny (Pritchard 1998; Anderson 2000), but more directly by providing opportunities for students to practice positive ethical decisions themselves through their design considerations, decisions, and interactions (real or hypothetical) with the people they wish to help.

1.2.5. CARE ETHICS

Care ethics itself has evolved as a distinct ethical theory in the academic literature in response to the work of feminist scholars of the 1970's and 1980's. Pioneering work by Gilligan (1982) in psychology was taken up by others, such as Noddings (1984/2003) in education, Kittay (1999) and Held (2006) in philosophy, and Tronto (1993) in political science. In the present work, I build on Tronto's (1993) framework, which describes care ethics in terms of four inter-related elements:

Attentiveness, Responsibility, Competence, and Responsiveness, plus a fifth meta-level element, Integrity, which integrates the four elements into a cohesive whole (see Section 2.2.1 for more on Tronto's framework). I chose Tronto's framework because it facilitates understanding both analytically through comprehension of its individual elements, and synthetically through the integration provided by the Integrity element as well as the inter-relations between its other elements. I feel that these features make it more accessible to an engineering audience than other formulations of care ethics that are less structured. Indeed, others have recognized the accessibility of Tronto's framework and elaborated on it in engineering contexts, including Pantazidou & Nair (1999), who mapped the elements to the engineering design and problem solving processes, and Kardon (2005), who conceptualized the framework as a standard of care for engineering, and Van Wynsberghe (2013), who adopted Tronto's framework specifically as a conceptual framework for doing value-sensitive design in the context of healthcare robotics.

Moving beyond Tronto's framework into the broader realm of care ethics in engineering, note that, because care ethics is a relatively new theory and because it is contextual (rather than universalistic), there are many formulations of care ethics and a number of different terms may be used. Some authors use the phrase "an ethic of care" to indicate it as one of many possible instantiations, while others use the phrase "the ethics of care" focusing on common features (see Held 2007). The phrase "ethic(s) of caring" is also used by some, as is the phrase "feminist ethics," which is a broader term that includes non-care-centered theories originating in the feminist literature.

In a full text search of the journal of Science and Engineering Ethics (1,375 articles from 1995 to 2015), I found 37 papers containing the phrases "care ethic(s)," "ethic(s) of care," or "ethic(s) of caring." However, about half of these occurred in the context of healthcare rather than engineering, and most gave only passing reference to care ethics rather than making it the focus of the work. The phrase "feminist ethic(s)" returned just four papers, three of which were relevant. These were: Riley (2013), who illustrated, among other things, how key aspects of care ethics are sometimes "lost in translation" when engineers try to apply them (e.g., Kardon 2005); Sunderland (2014), who showed the value of emotion in engineering ethics via problem-based learning and mentioned Pantazidou & Nair's (1999) work as drawing positive attention to emotion; and

Verharen et al. (2013a), who advocated for a new theory of “survival ethics” (see Verharen et al. 2013b) while very briefly comparing it to care ethics. Searching for the word “Tronto” returned just five papers, two of which were discussed above (Riley 2013; Van Wynsberghe 2013), and three of which made only passing reference to Tronto’s work in a paragraph or less (Dias 2003, 2011; Novitzky et al. 2014). Fruitful discussions of care ethics are also occurring in related fields, such as science and technology studies (STS) (e.g., see Bellacasa 2011),⁷ and business ethics (e.g., see Hamington & Sander-Staudt 2011).

1.3. CONTRIBUTIONS OF THIS RESEARCH

This dissertation adds to the literature an empirically informed perspective in different disciplines and contexts, and focuses more deeply on individual elements of Tronto’s framework. Plus, to my knowledge, neither Tronto’s framework nor any other framework for care ethics has yet been used as a lens to explore empirical data in engineering educational research, especially data collected to better understand how care might be reflected in engineers’ responses to situations that elicit caring, such as in problems of humanitarian or social justice nature. This work helps to fill that gap and contributes to a better understanding of both how engineers can theoretically and practically be more ethically caring in their work, as well as how care ethics is manifested in work performed by engineering students in humanitarian and social justice contexts today. The contributions of this work to the field of engineering education include:

- furthering the thought and dialogue needed to create change in the value system of engineering
- integrating concepts of care ethics into engineering and demonstrating its relevance, value and importance
- creating and demonstrating operationalizations of care ethics for use in research, teaching, and learning
- revealing student strengths and educational needs to develop skills of ethical caring (e.g, the elements of care that undergraduates can already exhibit, the extent to which they do so, and the areas in which growth may be needed)

⁷ With gratitude to an anonymous journal manuscript reviewer for pointing out this reference to STS work.

- identifying care ethics as a neglected dimension of engineering ethics and contributing a practical means of addressing that deficiency through the integration of humanitarian and social justice topics into the curriculum

This work helps pave the way for further research into the neglected application of care ethics to engineering, as well as informs educational policy makers of the potential value of (and cautions against) the use of humanitarian engineering and service learning, such as for developing cross-cultural empathy. It can also aid curricular efforts and inform pedagogical strategies, learning objectives, evaluations, and assessments of emerging and established engineering programs.

1.4. STUDY DESIGN

This study is guided by three overarching research questions: one explored conceptually, one empirically, and one that examines the educational implications of the work. The research questions (RQ), which are discussed in the following sub-sections of this chapter, include:

RQ1: How might care ethics manifest in engineering?

RQ2: In terms of care ethics, how do students in traditional engineering programs respond to problems of humanitarian or social justice nature?

RQ3: What are the implications of the above (e.g., on course design, curricular change, educational policy, engineering practice)?

Figure 1 gives an overview of the study design, illustrating the relationships between the research questions. In the case of the empirical research question (RQ2), the figure indicates more focused sub-questions as well as the data sets used to address them. The sub-questions of RQ2, are presented in Section 1.4.2 below (see Appendix C for a summary of all the research questions).

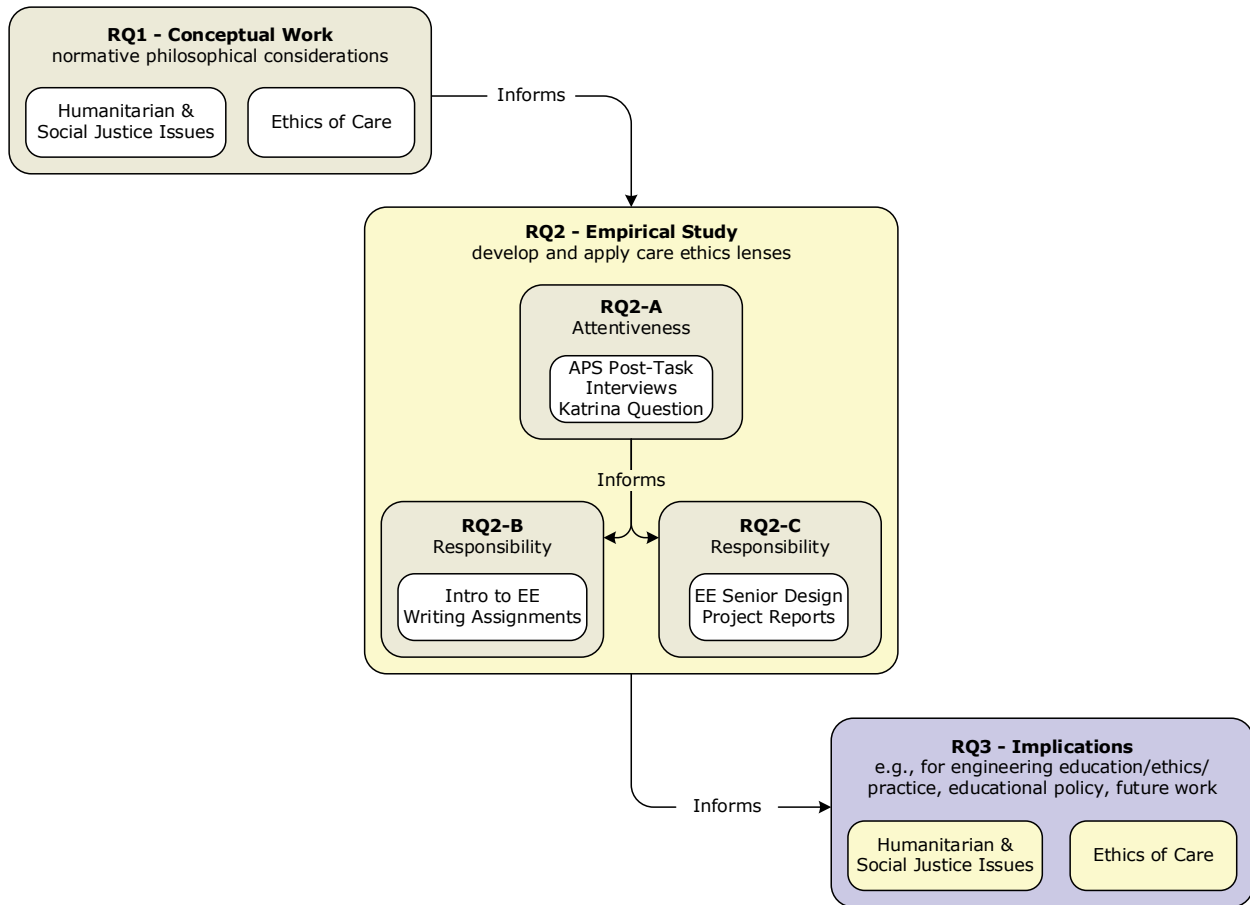


Figure 1. Research Study Design

1.4.1. CONCEPTUAL COMPONENT

Research Question 1: Manifesting Care Ethics in Engineering?

The conceptual work is performed under a critical theoretical framework by synthesizing and building on literature both inside and outside of engineering education, including philosophy and feminist theory. The response to RQ1 advocates for change in engineering education and serves to guide the remaining research questions and their analyses by identifying a lens through which to approach the subsequent empirical work.

In addressing RQ1, I argue that care—defined here as an active compassion, empathy, and concern for the wellbeing of other living things⁸—is not just a nice thing to do, but can be used as a guiding framework to help engineering education, and thereby engineering practice, contribute constructively to issues of social and ecological justice. One of the key outcomes from my early conceptual work was the identification of an “engineering-friendly” framework for understanding care ethics, which has also proved valuable in operationalizing care ethics for the purposes of qualitative empirical research. This framework was published by political scientist J. Tronto in 1993.

Tronto (1993) describes four interconnected and frequently overlapping phases of the care process: caring about, taking care of, care-giving, and care-receiving, which correspond to four moral elements of care: Attentiveness, Responsibility, Competence, and Responsiveness, respectively. Attentiveness (c.f. caring about), involves awareness of the needs of others and makes the claim that neglect and even ignorance, be it willful or inadvertently habitual, are moral failings. Responsibility (c.f. taking care of), involves the care-giver taking responsibility for involvement in the care relationship (be it voluntary or not). Competence (c.f. care-giving), indicates that the work of meeting an objective need must be not only performed, but it must be done competently so that the need is in fact met. Responsiveness (c.f. care-receiving), deals with the response of the care-receiver to the care-giver and includes consideration of the problems of inequality and vulnerability. Having thus described care ethics as a practice, to these four moral elements Tronto adds a fifth meta-level dimension, known as the Integrity of Care. The intended connotation of Integrity here is cohesiveness, joining together or integration; thus, just as good care results from the four phases being well-aligned and collectively appropriate, the four moral elements must fit together as an integrated whole in a way that is sensitive to context and addresses the conflict that is inherent in any moral situation. See Section 2.2.1 for more details on Tronto’s framework.

⁸ One could also make a case for the applicability of care to some non-living things. For example, one might be legitimately concerned for the “wellbeing” of the soil on one’s farm, or perhaps have compassion for a rocky mountain that is being strip-mined. However, in this dissertation I will limit care to considerations to living things.

1.4.2. EMPIRICAL COMPONENTS

While the conceptual component of this work attempts to describe an ideal of what care ethics might look like in engineering, it is unreasonable to expect reality to be very close to that ideal because, unlike other service professions such as nursing, medicine, or social work, care and concern for others has seldom, if ever, been an explicit pedagogical or professional consideration in engineering. Given the almost exclusively technical focus of most conventional engineering programs and coursework, recognizable opportunities to exhibit care in engineering may even be non-existent. Therefore, I will look at how care is reflected in engineering student work that is performed in humanitarian or social justice contexts, which provide easily recognizable opportunities for care.

A logical place to start is with the necessary precursors to caring actions/behaviors, namely, the first two elements of Tronto's care framework: Attentiveness and Responsibility (see above or in more detail in Sections 2.2.1, 3.1, 4.1.1 and 5.2). Thus, in terms of work performed in humanitarian or social justice contexts, Chapter 3 examines who or what engineering students are attentive to (i.e., "care about"), and Chapter 4 and Chapter 5 explore who students associate with responsibility (i.e., "taking care of") and ways in which they do so.

Research Question 2: Student Response to Humanitarian/Social Justice Problems?

There are a number of possible ways to approach answering the empirical research question, RQ2 ("In terms of care ethics, how do students in traditional engineering programs respond to problems of humanitarian or social justice nature?"). It is helpful to divide the question into three, more focused sub-questions that address the overarching research question more specifically:

- RQ2-A:** How do students exhibit Attentiveness ("caring about") in the context of natural disaster prevention?
- RQ2-B:** How do students exhibit Responsibility ("taking care of") in the context of "backyard" e-waste recycling?
- RQ2-C:** How do students exhibit Responsibility in the context of rural electrification?

Using different contexts, these questions each directly address one element of Tronto's care ethics framework; however, I should also point out that they indirectly reveal student potential in other elements of the framework as well. For example, poor attentiveness is not likely to result in responsibility-taking, flawed notions of responsibility will likely lead to incompetent care-giving, and so on. Collectively, the answers to these three sub-questions could potentially provide some level of coverage of all four phases of Tronto's framework. The fifth meta-level element of care, Integrity, could also perhaps be assessed by looking at student motivations for care,⁹ but that is beyond the scope of this dissertation.

In answering RQ2, I have chosen to adopt an interpretive theoretical framework and use qualitative data comprised of student self-reports and writing samples. Specifically, I have chosen a method of thematic analysis that seeks to capture the range or breadth of student conceptualizations in the interest of describing, analyzing, and understanding student strengths and limitations as a foundation to course/curriculum design and educational practice. The approach is somewhat phenomenographic (e.g., see Booth 1997), but I do not claim this to be a work of phenomenography. Neither is the approach *phenomenological*, as I make no attempt to capture a common, shared essence of student experiences (Chism, Douglas, & Hilson 2010; Case & Light 2011). Instead my approach seeks to capture the diversity of qualitatively different ways students express themselves and then to interpret them through a lens of care ethics. Details of the method and methodology as applied to each data set appear in their respective chapters (see Sections 3.2, 4.2, and 5.2).

As indicated previously in Figure 1, a different data set was used to address each sub-question (each sub-question has been contextualized to the data set). These data sets, which are summarized and characterized in Table 1 and further described below, include:

- A. brief interviews showing the ways in which students in 2006 said their knowledge of Hurricane Katrina (and its impact on New Orleans) influenced their design thinking on a

⁹ For example, perhaps the Integrity of Care can be considered a disposition that provides a motivational dimension of care ethics, to which the four phases and moral elements add operational "legs" for enacting the process of care.

- river retaining wall design task. This was used to explore who or what their Katrina-knowledge helped students be attentive to in a care-ethical sense (Tronto's Attentiveness).
- B. writing assignments providing student perspectives on ethical responses of engineers in the context of environmental and health problems created by "backyard" e-waste recycling in China and India. This was used to explore student notions of responsibility in a care-ethical sense (Tronto's Responsibility).
 - C. team-based design project reports illustrating the ways in which student teams approached preliminary designs for expanding a large-scale electric power system from an industrialized into non-industrialized region. This was used to explore the ways in which students would assume ethical responsibility in this context (Tronto's Responsibility).

The first data set was comprised of short student interviews that followed a 10-minute design scoping task conducted during year three (2006) of CAEE's Academic Pathways Study (APS). This APS interview data provided a broad view of third-year engineering students across multiple majors (largely computer science/engineering, mechanical engineering, chemical engineering and electrical engineering, but many others were included in the sample) and from four different institutions. It represented a distinctive opportunity to examine the influence of the tragic occurrence of Hurricane Katrina, the aftermath of which received copious media coverage in months prior to the collection of APS design task and interview data, on engineering design thinking. The APS design task employed a conceptually related question about designing a retaining wall for the Mississippi river. Hurricane Katrina thus provided a stronger, though implicit, humanitarian context—an opportunity for care—to the design task. The students were then asked via the post-task interview protocol about their knowledge of Katrina and the influence that it may have had on their responses. Responses to this last question were the focus of my analysis on this data set.

Table 1. Sources of Data

Source	Type (Context)	Level of Explicit Humanitarian/Social Justice Content	Date of Data Collection	Number of Available Data Points	Number of Data Points Analyzed
APS Y3 Post-task Interviews	Interview Transcripts (Research)	Med	2006 Spring	73*	73
Introductory Electrical Engineering Course	Writing Assignments (Class)	High	2011 Fall	84†	30
Senior Electrical Engineering Design Course	Project Reports (Class)	High	2009 Spring	12‡	2

* Interview responses indicating the influence of Hurricane Katrina on design task responses (question was not asked of all participants: 59% effective response rate).

† Writing assignments on the topic of waste electrical and electronic equipment recycling in China and India (assignment was optional/extra-credit and not completed by all students: 56% response rate).

‡ Project reports on electric power system design written by 12 groups of 3 students (assignment was required and completed by all student groups: 100% response rate).

The second data set, comprised of writing assignments, provided a more detailed view of a narrower selection of engineering students (predominantly third-year electrical engineering and mechanical engineering majors, though many other majors were also included in the sample) from a single institution and a single course. These assignments involved first reading selections of a journal article on the environmental impacts of waste electrical and electronic equipment (e-waste) recycling in China and India and then responding to a prompted essay-style writing assignment. The assignment asked for student responses to what concerned them the most about the resulting environmental pollution transport cycle, how that concern affects humans and the ecosystem, and what engineers should do about the waste recycling dilemma as an ethical response. Responses to this last question were the focus of my analysis on this data set.

The third data set, comprised of design project reports, provided an even more detailed view of an even narrower selection of engineering students: senior electric power engineering student teams from a single institution, department, and course. These project reports involved an explicitly humanitarian / social justice context that was built in to the design project's problem statement. Building on course materials developed and refined by others (see Hines & Christie 2002), the students were asked to perform studies of the transient stability of a modern electric power transmission grid and recommend improvements to accommodate load growth. They were also asked to recommend options for extending this power system into an adjacent non-industrialized region in a way that showed how environmental, social, and ethical considerations were taken into account. Responses to this last question were the focus of my analysis on this data set.

Table 2 highlights the differences among RQ2 sub-questions. The answers to these sub-questions provide multiple, complementary ways of addressing the overarching research question – a form of triangulation, since data comes from multiple sources both in terms of subject populations and types of data. In general, sampling followed the principle of maximum variation, with data coming from a wide variety of engineering departments/majors. Variation in type of data is also present through the use of interviews, short writing assignments, and open-ended design project reports. The nature of each successive data set also provides a deeper and more contextualized view of care in engineering. For example, the differences in the type of educational experience provided by each humanitarian/social justice context, as described above, cover a variety of approaches to ways of introducing such context in the classroom: from the implicit or reflective invocation of Hurricane Katrina in the APS interviews (see Section 3.2), to the explicit and highly scaffolded prompting of the writing assignments (see Section 4.2.2), to the project-integrated context of the design project reports (see Section 5.1.1).

Table 2. Comparison of RQ2 Sub-questions and Data Source Details

Question	Context	Year in college	Engineering Major	Data type	Data source
RQ2-A	humanitarian disaster-related design task	3rd	many*	conceptually-related design task	APS Y3 Post-task Interviews
RQ2-B	environmental & health impacts of e-waste recycling in China & India	2nd & 3rd	many†	prompted writing assignment	Introductory Electrical Engineering Course
RQ2-C	electric power system expansion in the developing world	4th	electric power systems engineering	capstone design project	Senior Electrical Engineering Design Course

* Largely chemical, electrical, mechanical, and computer science/engineering, but many others were also included in the sample, including aeronautical/astronautical, bioengineering, civil/environmental, industrial, metallurgical/materials, petroleum, physics/engineering physics, and technical communication.

† Largely mechanical and electrical engineering, but others were also included in the sample, including bioengineering, civil/environmental, industrial, materials science/engineering, computer science/engineering.

Limitations / Possible Threats to Validity/Credibility

The sample sizes of the data associated with each sub-question are not large and not intended to provide statistical significance or generalizability. Instead, the data provide a rich understanding of how students respond in contexts of humanitarian or social justice nature. Such knowledge supports understanding what makes these contexts differ from more conventional contexts in undergraduate engineering education and, in conjunction with the philosophical foundation addressed in RQ1, can lay a strong foundation for the integration of care ethics into undergraduate curricula. The focus of these empirical research questions is thus on exploring and describing (and thereby seeking to better understand) the different ways in which engineering students are influenced by these contexts. Proving cause and effect, however, is outside the scope of this research as it would require a more focused form of operationalized assessment and randomized controlled trials. The outcomes of this study would be useful in developing an intervention-based study in the future, such one that compares the influence of humanitarian/social justice contexts with other types of engineering contexts (like those of a more traditional commercial, industrial,

or military nature). However, for the present study using the aforementioned data sets, attempting to prove causality would be trivial:

- For the APS data, the students first completed a design task and were then asked to self-report the influence of their a priori knowledge of Hurricane Katrina on their responses. While we might question the authenticity of their responses due to the possibility of social desirability bias, the interview question itself clearly establishes the causal link between humanitarian context and subject response.
- For the writing assignments, the students were given selections from a journal article to read about the environmental impacts of e-waste recycling in India and China. They were then prompted with questions about the article (i.e., what concerned them the most, how that concern affected humans and the ecosystem, and what engineers should do about it as an ethical response). It is hard to imagine possible responses that do not reflect the context provided by the article.
- Similarly, for the design project reports, the students were explicitly prompted by the problem statement materials for their responses to a problem of humanitarian/social justice nature, thus causality is not in question.

The bullet points above, however, do point out some threats to credibility (a qualitative analog to the quantitative notion of internal validity) that should be considered, and where possible, addressed. For example, the issue of the possibility of social desirability bias in the APS (RQ2-A) data could be raised. This and other possible limitation are discussed later in the respective chapters (see Sections 3.5, 4.5.2, and 5.4.1).

1.4.3. EDUCATIONAL AND BROADER IMPLICATIONS COMPONENT

This component of the work serves to generate implications of the findings from within and across the three sub-questions of RQ2. While it might be more conventional to subsume the implications (e.g., on course design, curricular design, educational policy, engineering practice) into the discussion of findings in the empirical component of the work, the importance of these implications have instead been highlighted by posing the third research question (RQ3: What are

the implications of the above (e.g., on course design, curricular change, educational policy, engineering practice)?). Implications for each of the RQ2 sub-questions appear in their respective chapters (see Sections 3.6, 4.5.3 and 5.4.2), and a higher-level synthesis of these implications appears in the concluding chapter, Chapter 6.

1.5. STATEMENT ON RESEARCHER POSITIONALITY (I.E., WHO AM I?)

In this section, I describe my personal background as it relates to my motivations for pursuing this research and the imprint it leaves thereon. As with any research, one's background influences not only one's motivations, but also the ways in which the research is conducted; especially with qualitative/interpretive research, awareness of this background is important for the researcher to maintain, and helpful for the reader to understand.

1.5.1. RESEARCHER BACKGROUND AND DEMOGRAPHICS

I grew up in the western mountain region of the United States and come from a white, middle-class American family of European descent. Unlike most of my peers, who were either Christian or non-religious, I was raised as a Bahá'í [pronounced "ba-**high**"]. The Bahá'í Faith is a relatively new, independent religion that views the earth as one country and humanity as one people, and is one of the most geographically widespread religions in the world.¹⁰ Learning, teaching, humanitarianism, and philanthropy are core aspects of the Faith. Bahá'ís view science and religion as necessary, complementary means through which humankind strives to understand Truth. We recognize the Divine origins of previous religions, such as Buddhism, Christianity, Hinduism, Islam, Judaism, and Zoroastrianism, and see them as part of an ongoing process of religious evolution and renewal that advances human society. Bahá'ís everywhere work to abolish prejudice in all its forms, especially those based on race, sex/gender, and religion.¹¹

¹⁰ According to Encyclopedia Britannica, the Bahá'í Faith is second only to Christianity in terms of number of countries represented—see <https://www.britannica.com/topic/religion-Year-In-Review-2010> and <https://web.archive.org/web/20060221044201/http://www.britannica.com/eb/table?tocId=9394911>

¹¹ For more information about the Bahá'í Faith, see www.bahai.org and/or find the website for the Bahá'ís in a particular country at <http://www.bahai.org/national-communities>

Thus, the teachings and values of the Bahá'í Faith both motivate and permeate my work. For example, the Bahá'í teaching of the equality of women and men leaves me open to respecting and utilizing research from feminist scholars (who brought care ethics to the fore in academic circles). Additionally, the Bahá'í teachings on race unity and social justice make me keenly aware of the white, male dominance of engineering in the U.S. The lack of gender and racial diversity in engineering is a problem that motivates this work and one that has impacted the study design and methodology, as described below.

Another relevant demographic is gender: I am male, heterosexual, and cisgender (i.e., my gender identity matches my biological sex); however, performing this research has made me aware of my tendency toward traits that are stereotypically feminine (e.g., kindness, sensitivity, and humility) rather than masculine (e.g., strength, assertiveness, dominance, and control). One might say I am in touch with my feminine side in various ways and/or fit many of the characteristics of the so-called “herbivore men”, which include a gentle nature, viewing women as equals, and not being bound by social expectations of manliness (see Morioka, 2013, p. 13, Table 1). These characteristics have clearly influenced my choice of research topic and provide me with a unique perspective on engineering education.

Finally, parental influence has impacted my work. During childhood, my father worked as an engineer and my mother was a writer and homemaker, so I had familial influences encouraging my interest in both the humanities and STEM (science, technology, engineering, & mathematics). In high school, I had enjoyed and excelled at math, physics, and music, and I considered majoring either in engineering or instrumental music in college. Thus, my interests and abilities are diverse, inclining me toward work that is interdisciplinary in nature.

1.5.2. RELEVANT EDUCATIONAL AND LIFE EXPERIENCES

I approach this research having both studied and worked in engineering in several different universities and several different countries. My undergraduate (a.k.a., postsecondary) education began near my hometown at a small, public research university that focused on engineering and applied science. I majored in Engineering Physics and minored in Electrical Engineering but found

that the abstract, theoretical and impractical nature of these subjects made them difficult, dry, and unfulfilling. I was also very much aware of the gender imbalance in the undergraduate population, which I have since learned was 74% male at this school the year I began my studies. Finally, I found the engineering monoculture that pervaded the school to be stifling: it was difficult, if not impossible, to interact with people who did not also eat, sleep, drink, and think engineering. After three-and-a-half years at this university, I finally burned out and quit school for several years. This experience left me with a perception of engineering education as cold, narrow technical/mathematical, and lacking in diversity both in terms of demographics and subject matter.

After several years of working in retail management, I decided to finish my undergraduate degree at another university in the same state. This school was a large, public research university: a land-grant institution and thus had a somewhat more practical and service-oriented culture than my previous university. Here, I changed my major to Engineering Science, a broad degree combining the four major branches of engineering (Chemical, Civil, Mechanical and Electrical), and chose a concentration in Environmental Engineering, which I tried to approach more in terms of sustainable design than mitigation/remediation as encouraged by the curriculum. At this school, I was able to take a wider variety of elective courses, such as philosophy and psychology, and I very much enjoyed tutoring biology and organic chemistry. I still noticed the gender imbalance in most of my engineering classes (graduation rates show it was 80-85% male in engineering during my tenure versus 49% male across all academic disciplines campus-wide); however, at this school I was able to interact with a much wider variety of people having different backgrounds and interests. This experience restored my hope that I could find a meaningful career in engineering.

However, after graduation, I had little interest in working as an engineer in the service of either consumerism or the military-industrial complex: I wanted to do something more altruistic. I considered applying to the Peace Corps, but decided instead to volunteer at the World Centre of the Bahá'í Faith in Haifa, Israel, where I served as a building control systems engineer/technician for several years. The work itself was primarily technical in nature, requiring knowledge of mechanical, electrical, and computer engineering, but it was also very practical, combining design, troubleshooting, hands-on commissioning/repair, and interaction with a diverse, international population. Looking back, I realize that the gender diversity of my immediate co-workers was no

better than it was at either of the engineering colleges I attended, but the combination of work-task diversity, racial/ethnic diversity of co-workers, and opportunities to interact with “end users” gave me hope about what an engineering career could be in terms of breadth, diversity, and opportunities for care.

After serving in Haifa, I moved to Korea (my spouse’s home country) and worked in a university language institute teaching English conversation. I enjoyed teaching and decided to attend graduate school there to gain the necessary credentials to teach other subjects. I joined a research lab and studied Electrical Engineering with a focus on utility grid-connected solar-photovoltaic electric power systems. Renewable energy systems appealed to me given my undergraduate interest in electrical engineering and sustainable design. However, the experience was in some ways similar to that at my first university because of its narrow, technical focus and lack of diversity. In fact, there were very few non-Korean students in Korean universities at that time (the nationwide international student population grew from about 2% to 4% during my tenure) and engineering in Korea is even more male dominated than in the U.S. (Korean national statistics reveal graduate student enrollment in engineering during my tenure was 87-88% male). Thus, my perception of engineering education as cold, narrow, technical/mathematical, and lacking in diversity (both in terms of demographics and subject matter) was confirmed in a second university and country.

After completing my Master’s degree in Korea, we moved to the U.S., where I began a doctoral program in Electrical Engineering with a focus on computer modeling of electric power and renewable energy systems. While this was a very good program and I had an excellent advisor, I found the narrow, technical focus, and exclusively mathematical approaches to problem solving to be stifling and at odds with the more practical, intuitive way I approached engineering. Furthermore, I wanted to add an explicitly educational component to my degree, but was advised by several in the department (not my advisor) to finish my technically-focused degree before indulging my education interests. Realistically, there was no room in the curriculum for anything more than the required major in one sub-discipline of Electrical Engineering and the required minor in another sub-discipline of Electrical Engineering.

When my advisor accepted an enviable job offer from another university in another country, I took the opportunity to change programs for one that could better value and support my interest in education: the Individual Ph.D. Program. With the help of a great, new advisor, this program has allowed me to create my own course of doctoral study in the emerging field of Engineering Education, with advisory committee members in a variety of departments, including Education, Electrical Engineering, and Human-Centered Design & Engineering. My experience in engineering at this school further confirmed my perception of engineering education as cold, narrow, technical/mathematical, and lacking in diversity. Fortunately, I had the opportunity to move into another program better suited to my strengths and interests, and pursue research that I hope can address some of the problems I perceive in engineering education.

1.5.3. EFFECTS OF BACKGROUND AND EXPERIENCES ON THIS RESEARCH

At a high level, my background and experiences pervade the work by motivating it, influencing the things I see and the ways I see them, coloring my interpretations and means of expression. My experience of engineering education as being cold, narrow, technical/mathematical, and lacking in diversity (both in terms of demographics and subject matter) at three of the four universities I attended has created in me the desire to make space in engineering for the breadth, diversity, and opportunity for caring that much of my education lacked. As a result of this, I may unconsciously (and sometimes consciously) voice some of my frustrations with engineering education by using a tone that may appear harsh and overly critical for some readers. For some branches of engineering, like industrial/systems engineering, bioengineering, or human centered design & engineering, elements of the breadth, diversity, and caring may already be present in the curriculum and practice, and thus some of the positions I take may not seem fully warranted. Since Electrical Engineering is the branch I know best (having survived electrical engineering courses taken at four different universities in two countries), it represents the perspective from which I write. While my value positions may be very reasonable for some readers, I recognize that others may need to set them aside and assess the degree to which my work applies to their particular field or program. Hopefully I have written and structured the document to facilitate this.

While I acknowledge there are elements of perspective and bias that are impossible to avoid when performing any kind of research, there are ways in which I have attempted to keep my biases and predispositions in check while performing the work, especially for the empirical components. In alignment with my values, an important issue for me was to give voice to a variety of perspectives that appear in the data. Consequently, I used a methodology that sought to capture breadth of responses rather than prevalence (see Section 1.4.2). I also made conscious decisions regarding data choice and sampling to ensure that the perspectives of underrepresented minority students were privileged rather than silenced: namely, by using an existing data set that had oversampled for women and racial/ethnic minorities (see Section 3.2), by my own oversampling for women and non-U.S. citizens (see Section 4.2.3), and by choosing cases based on their contrast with each other as described in Section 5.2.3.

With these values and strategies, however, come potential biases that I also took measures to mitigate. For example, despite my Bahá'í upbringing, I am not immune to the effects of cultural stereotypes like those suggesting women to be more attuned to caring and care ethics. Also, I was aware of related literature, such as that suggesting similar caring tendencies in men from some African cultures (see Held 2007). In an attempt to limit the impact of these potential biases, I anonymized the data to ensure analysis was performed without knowledge of potentially relevant participant demographics (i.e., institution, race/ethnicity, and gender for the APS data in Chapter 3, race/ethnicity, gender, and citizenship for the writing samples in Chapter 4, and gender breakdown and other characteristics of the group members for Chapter 5), lest that knowledge influence coding and interpretation. Participant demographic data was only brought back in when choosing sample quotes during write-up and to help ensure a variety perspectives were represented. While it is beyond the scope of this work to test hypotheses around these issues, I did perform some preliminary statistical analyses with one of the data sets that suggested possible institutional, but not gender differences (see the last paragraph of Section 3.6.2).

Finally, another predisposition I was aware of and attempted to address was much longer term in its mitigation and effect. Through my engineering training, I am predisposed to quantitative ways of thinking (engineers typically work with numbers a lot), and have found qualitative/interpretive mindsets more difficult to internalize. The three empirical pieces in this

work are presented chronologically in order of analysis and serve to reflect my increasing comfort with qualitative/interpretive and conceptual work. This is visible, for example, by the progression from using multiple coders and a relatively large data set ($n = 73$) in Chapter 3, to the single coder and smaller data set ($n = 30$) in Chapter 4, to the comparative case study approach ($n = 2$) in Chapter 5. This is also visible in my increasing integration of conceptual and empirical work across these three chapters.

As I learned more about qualitative research methods and methodologies, I came to better appreciate their strengths, especially when attempting research in areas that are new and not well understood like care-ethics in engineering. Attempting to impose quantitative, positivist standards of rigor with such measures as inter-rater reliability on constructs that are only very coarsely defined is usually not a very good use of time. Instead, there is much to be learned (and more efficiently) by working as a single coder and vetting one's ideas with colleagues or advisors. Coming into this research from a field like engineering, where people employ positivist and/or post-positivist epistemologies (usually without even being aware that there are other ways of knowing about world), it took me some time to understand and value alternative approaches to research like those used by the interpretivist and critical perspectives. For example, the idea of performing a case study in my dissertation initially seemed inappropriate to me because small sample sizes make generalizable knowledge claims impossible. However, what case studies lack in breadth they can make up for in depth, providing important contextual insights that are missed by other approaches.

1.6. ORGANIZATION OF THE DOCUMENT

In Chapter 2 I begin the core work of the dissertation by introducing care ethics, identifying a useful framework for it, and then using it for conceptual explorations of care in the engineering profession. I then point out some potential barriers and next steps to making engineering practices more care-ethical. The next three chapters build on the conceptual work, adding an empirical dimension by exploring engineering student responses in three different engineering contexts that involve problems of a humanitarian and/or social justice nature. Specifically, in Chapter 3, I operationalize one element of care ethics and use it to look at the ways in which students in 2006

said their knowledge of Hurricane Katrina (and its impact on New Orleans) influenced their design thinking on a river retaining wall design task. In Chapter 4, I operationalize another element of care ethics and use it to explore student writing on the topic of engineers' responsibilities for the human health and environmental impacts of "backyard" electronic waste (e-waste) recycling that presently occurs in many industrializing countries, such as India and China. Then, in Chapter 5, I use a comparative case-study approach to look, again through a care-ethics lens, at the ways in which student teams approached preliminary designs for expanding a large-scale electric power system from an industrialized into non-industrialized region. Finally, I conclude in Chapter 6 with a summary and synthesis of the work.

Chapter 2. How Can Engineers Learn to Care?

This chapter addresses the conceptual research question (RQ1) and sets out the conceptual framework for care ethics utilized throughout the rest of the dissertation. It is comprised largely of the book chapter¹ I contributed to *Engineering Education for Social Justice: Critical Explorations and Opportunities*, an edited volume published in the Fall of 2013 by Springer in a book series called “Philosophy of Engineering and Technology” (see <http://www.springer.com/series/8657>). The final publication is available at Springer via http://dx.doi.org/10.1007/978-94-007-6350-0_6

¹ Campbell, R. C. (2013). How Can Engineering Students Learn to Care? How Can Engineering Faculty Teach to Care? In J. Lucena (Ed.), *Engineering Education for Social Justice: Critical Explorations and Opportunities*, Philosophy of Engineering and Technology (Vol. 10, pp. 111–131). Dordrecht, Netherlands: Springer. http://dx.doi.org/10.1007/978-94-007-6350-0_6

2.1. INTRODUCTION

Many of the inhabitants of Asia, Europe, North America, and other parts of the world are indebted to the engineers of the past and present for improving their lives through the practical and sometimes artful application of science to real world problems in fields as diverse as transportation, communication, and health care, just to name a few. However, engineering as a profession has historically served the needs and interests of only a limited portion of human society. In fact, not only have large numbers of people, including most in Africa and South America, failed to benefit from the work of engineers, many in countries around the world have even suffered, either directly from the weapons engineers created, or indirectly through unintended consequences related, for example, to pollution and environmental degradation created by technology and the levels of production and consumption technology has enabled. How then can we, as conscientious engineers of today, learn from the past and work toward a future that takes better care of both the people we profess to serve and the ecosystem in which we attempt to do so?

This chapter focuses on a missing dimension to the traditional engineering experience that is located, at least initially for engineering, in the non-profit sector. This missing dimension is care, defined here as an active compassion, empathy, and concern for the wellbeing of other living (and in some cases non-living) things. Although care is an explicit component of education in other service professions, such as nursing, medicine, social work, and teacher education, care and the related concept of empathy have never been a focus of engineering education. The definition of care I have adopted contains two aspects that are worth pointing out: (1) use of the word *active* indicates that care is a practice and involves work or taking action, and (2) use of the words *compassion*, *empathy* and *concern* indicate an important dispositional or motivational component to care. Indeed, as the literature on care ethics in a variety of fields clearly shows, the concept of care has myriad dimensions and can be defined in quite a number of different ways (Hamington & Sander-Staudt 2011). The second chapter of philosopher and care ethicist Virginia Held's (2006) book, which is arguably the most comprehensive examination of care ethics to date (Hawk 2011, p. 13), provides a review of the literature on conceptions of care that shows how care can be defined as an attitude, a motive, a value, a virtue, a relationship, a habit, a practice, work or labor, the meeting of objective needs, a normative concept (often contrasted with justice), and even combinations of these. This variability, rather than being a burden, can actually be advantageous

because it provides the concept with a degree of *flexible adaptability* (Hamington & Sander-Staudt 2011, p. ix) with which it may be constructively applied to many different situations and conditions. In my usage of the term I wish to consider both the practice of care (e.g., the meeting of needs) and the attitudinal/motivational aspect of care because I join others (e.g., Riley 2008a; Lucena, et al. 2010) in the belief that engineers must reflect on their motivations and consider how those motivations might affect their attempts to understand and constructively interact with others.

The chapter begins with an introduction to the ethics of care, a normative ethical theory that emphasizes concern, responsibility, and context over rules or consequences. I then give an overview of care in the engineering profession that shows how altruism and care are currently manifest in engineering practice. Throughout the chapter, a five element framework for care ethics adopted from the literature is used as a guide to demonstrate how engineers can become more effective at caring in work related to philanthropic programs such as engineering for community service, disaster recovery, and international development. I will refer to these endeavors collectively as humanitarian engineering (H.E.), which, although perhaps a patronizing designation (Vandersteen 2008, p. 297), is widespread compared to other possible designations² and conveys some of the intended sense of caring shared by these endeavors. However, in spite of the obvious opportunities for care in H.E, the practice of ethical caring is wrought with pitfalls, which are discussed, followed by a way to overcome them through a proposed mindset that

² While there are a few other terms in the literature that are perhaps less patronizing of the care-receivers, such as “engineering to help” (Schneider et al. 2009), “global development engineering” (Riley 2008b), and “engineering with community” (Lucena et al. 2010), none have anywhere near the widespread recognition of the term “humanitarian engineering.” As evidence for this prevalence, I point to the following:

- a North America-based scholarly journal with H.E. in its subtitle, namely the International Journal for Service Learning in Engineering: Humanitarian Engineering and Social Entrepreneurship (<http://library.queensu.ca/ojs/index.php/ijse/index>) and an Australia-based journal with the title Journal of Humanitarian Engineering (<http://www.ewb.org.au/explore/knowledgehubs/education/journal>)
- academic minor and certificate programs of H.E., such as the Humanitarian Engineering Program at Colorado School of Mines (<http://humanitarian.mines.edu/>), and the Humanitarian Engineering and Social Entrepreneurship (HESE) program at Penn State University (<http://www.sedtapp.psu.edu/humanitarian/about.php>)
- a two part special issue of the IEEE Technology and Society Magazine entitled “Volunteerism and Humanitarian Engineering” (Vol. 28, No. 4 and Vol. 29, No. 1) and an IEEE conference titled Global Humanitarian Technology (<http://www.ieeeeghtc.org>)
- the recognition of 2011 as the Year of Humanitarian Engineering by Engineers Australia (<http://makeitso.org.au/yohe>)
- various academic publications that employ the term, such as Mitcham & Munoz’s (2010) book, Passino’s (2009) journal article, and VanderSteen’s (2008) Ph.D. dissertation

encourages humble, dialogical and egalitarian interaction. This chapter shows that, through the opportunities for ethical caring H.E. provides, engineers have a distinctive opportunity to become more willing and better able to contribute constructively to issues of social and ecological justice.

2.2. CARE ETHICS DEFINED

In contrast to the somewhat ambiguous definitions of care mentioned above, definitions of the *ethics* of care tend to be more structured and concrete. While a comprehensive review of all extant definitions is beyond the scope of this chapter, it is helpful to look at a few characterizations to understand the relationship between care and care ethics, as well as the relationship between care ethics and social justice. Indira Nair, professor of engineering & public policy, gives a concise description of care ethics as emphasizing “the importance of responsibility, concern, and relationship over consequences (utilitarianism) or rules (deontology)” (Nair 2005). Nel Noddings, feminist author and professor of educational philosophy, was one of the first to articulate an ethics of care. She distinguishes between natural caring, which, for example, most mothers gladly do for their children, and ethical caring, by which one is obligated to care regardless of one’s own personal desire (Noddings 2003). Noddings also points out the important difference between care ethics and social contract theory: social contract theory assumes an egalitarian reciprocity that is often not possible in cases of ethical caring, such as those occurring in parent/child and teacher/student relationships.

2.2.1. TRONTO’S FRAMEWORK FOR ETHICAL CARING³

Political scientist and care ethicist Joan Tronto (1993) has demonstrated how care ethics applies to not only the interpersonal or micro-ethical situations we commonly think about in regard to caring, but also to political/societal or macro-ethical situations. Tronto first frames care ethics primarily as a practice and describes four interconnected and frequently overlapping phases of the care process: caring about, taking care of, care giving, and care receiving. These phases then map

³ This sub-section is expanded and adapted from a conference paper written by the author (see Campbell, Yasuhara & Wilson 2012).

to four moral elements of care: Attentiveness, Responsibility, Competence, and Responsiveness, respectively. Her conceptualization of care ethics are particularly helpful when applying care ethics to engineering later in this chapter, thus I will describe it here in some detail. Note that I use the terms “phases” and “elements” somewhat interchangeably in referring to these aspects of care/ethics because the distinction between care and care ethics is not always necessary and it is often helpful to keep the progressive and/or cyclic nature of care in mind through use of the term “phase” even when talking about the moral elements.

Tronto’s first moral element of care, *Attentiveness* (c.f. caring about), involves awareness of the needs of others and makes the claim that neglect and even ignorance, be it willful or inadvertently habitual, are moral failings. Here she describes as an example the failure of many wealthy people in industrialized countries to notice (in spite of worldwide information & communication technology and diverse media coverage) how “activities spurred by a global capitalist system result in the starvation of thousands, or in sexual slavery in Thailand” (p. 128).

Tronto’s second moral element of care, *Responsibility* (c.f. taking care of), involves the care-giver taking responsibility for his or her involvement in the care relationship, be that relationship voluntary or not. Here she makes the point that responsibility differs from obligation, because responsibility, being contextual rather than universal, is more ambiguous, and may not even be associated with prior actions of the care-giver. Here she points, as an extreme example, to the benevolent actions of Europeans during the second World War who, at great peril, tried to rescue Jews from Nazi persecution because they felt responsible simply by virtue of being human (p. 132).

Tronto’s third moral element of care, *Competence* (c.f. care giving), indicates that the work of meeting an objective need of the care-receiver must not only be performed, but it must be done competently so that the need is in fact met. By making competence in care-giving a moral necessity, insincere attempts at care-giving are considered moral failings. While there may be reasons beyond the care-giver’s control that impede adequate care, such as resource supply interruptions, as long as the care-giver does the best with what he or she has, the onus of any moral failing in Competence is on the party responsible for that resource deficiency. The example Tronto

gives is that of a teacher required by his or her school to teach a subject in which he or she has no background. Since the students will not likely learn the intended material, it is the school's failing not the teacher's (provided the teacher has made reasonable efforts in good faith to redress the situation). This moral element of care is thus particularly pertinent to professional ethics, which has long been of interest to engineers and engineering educators. It provides ethical grounds for preventing "individuals to escape from responsibility for their incompetence by claiming to adhere to a code of professional ethics" (p. 134).

Tronto's fourth moral element of care, *Responsiveness* (c.f. care receiving), involves the reaction of the care-receiver to the care given and includes consideration of the problems of inequality and vulnerability that are present in any caring situation (p. 134). Responsiveness is the feedback loop by which the care-giver can determine if the care provided is accepted by and effective for the care-receiver. This moral element of care, like Noddings' conception of care ethics above, challenges the common notion underlying conventional ethical theories that all individuals are equal, self-supporting and entirely autonomous. The fact that power imbalances exist and that individuals are unequal, interdependent and even vulnerable has important implications at the societal level as well. This is essentially the link between care ethics and social justice (more on this in the next subsection).

Having described care ethics as a practice, Tronto adds to these four moral elements a fifth meta-level dimension, known as the *Integrity of Care*. The intended connotation of integrity here is cohesiveness, joining together or integration; thus, just as good care results from the four phases being well-aligned and collectively appropriate, the four moral elements must fit together as an integrated whole in a way that is sensitive to context and addresses the conflict that is inherent in any moral situation, be it micro- or macro-ethical as traditionally understood. The Integrity of Care can also be considered a disposition (Hawk 2011, p. 8) ⁴ that provides a motivational dimension

⁴ Post-publication clarification: Hawk (2011) talks about Tronto's care ethics as being both a disposition and a practice, but does not link disposition to Integrity of Care, nor suggest that Integrity provides a motivational dimension (both of which may be implied by this sentence). Neither do these ideas appear in Tronto (1993, 2013), Pantazidou & Nair (1999), Held (2007), Hamington & Sander-Staudt (2011), nor Sander-Staudt (2011); thus, unless I later find that I inadvertently picked them up from another source, I should clarify these ideas are my own.

of care ethics, to which the four phases and moral elements add operational “legs” for enacting the process of care. Tronto’s entire framework for care ethics is roughly summarized graphically in Figure 2 and can be described as an interconnected and sometimes overlapping sequence of these five elements.

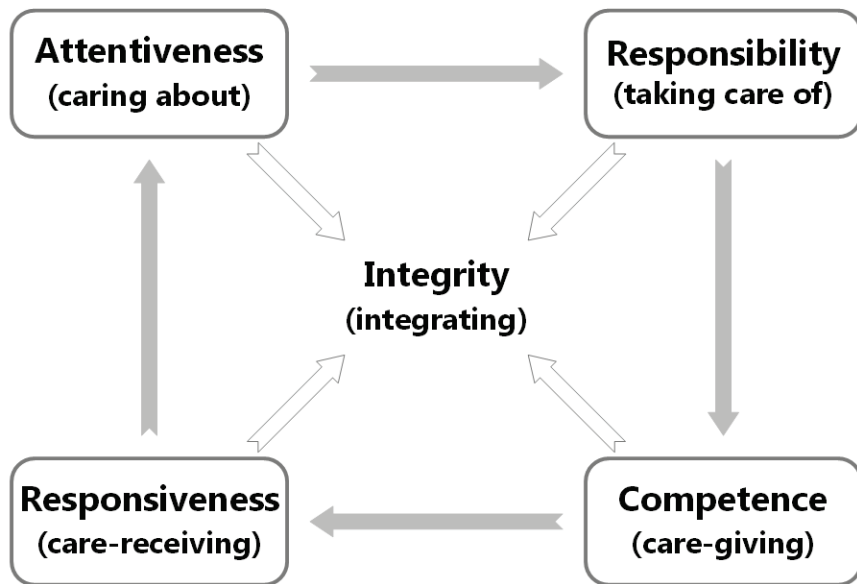


Figure 2. A Graphical Adaptation of Tronto’s Framework for Care Ethics⁵

2.2.2. CARE ETHICS IN THE ENGINEERING EDUCATION LITERATURE⁶

In the engineering education literature, which I review below, care ethics has not attracted much interest to date. However, it has received considerable attention not only in the fields of philosophy, education and political theory as the previous section suggests, but also in fields that are more obviously related to care such as nursing and medicine. Care ethics has also received attention in the fields of law, business ethics (e.g., Hamington & Sander-Staudt 2011), stakeholder theory (e.g., Engster 2011), knowledge & creativity management, and accounting. For a concise but more comprehensive review of this wider literature, see Hawk (2011 p.16-17).

⁵ Figure 2 is from Campbell & Wilson (2016) and was adapted from Campbell, Yasuhara, & Wilson (2015).

⁶ This sub-section is expanded and adapted from a conference paper written by the author (see Campbell, et al. 2012).

In the engineering education literature, the first mentions of care ethics appear as recently as 1997, when civil engineering educators Broome and Peirce, citing Noddings and Tronto, stressed “caring” principles as the motivation needed for engineers to become good, responsible, and even “heroic” in their practice (Broome & Peirce 1997). In 1999, Nair and civil engineering professor Pantazidou published the first engineering education journal article dedicated to understanding how care ethics might be manifest in engineering (Pantazidou & Nair 1999); they highlighted the service-oriented nature of engineering and illustrated its applicability to engineering design and problem solving methodologies by mapping aspects of these methodologies to Tronto’s elements of care. Specifically, for design methodology they associated:

1. Attentiveness with the identification of need in the context of the state of the art
2. Responsibility with design conceptualization
3. Competence with feasibility analysis and production
4. Responsiveness with customer acceptance
5. Integrity with the iterative nature of design

Similarly, for problem solving a given need, they associated:

1. Attentiveness with defining the problem in context
2. Responsibility with selecting a solution
3. Competence with executing a solution
4. Responsiveness with verifying that the solution is appropriate for the context

Professional structural engineer Joshua Kardon (2005) conceptualized care as a “standard of care” that essentially serves as a measure of ethical adequacy of the exercise of the engineer’s professional duties. In my view, this conceptualization aligns best with Tronto’s Competence phase of care ethics, though Kardon demonstrated, through the use of multiple case studies, how all five of Tronto’s moral elements could be used to evaluate the performance of engineering work against his “standard of care”. Finally, engineering professor Donna Riley (2008a) gave brief indications of the importance of care ethics in relation to engineering and social justice.

These conceptualizations, however, are somewhat abstract and lack an interpersonal nature of care as an active compassion, empathy, or concern for the wellbeing of others. One author who

did well in articulating the interpersonal nature of care in engineering was electrical engineering professor Gene Moriarty. While initially published outside of the engineering education literature (see Moriarty 1995), he provided an excellent introduction to care in engineering in an interpersonal sense through the use of virtue ethics (Moriarty 2008). Tempering care with objectivity, he presented a balanced conceptualization for both good engineering and the good engineer. Similarly, chemical engineering professor William Bowen (2009) proposed an aspirational approach to engineering ethics (also based on virtue ethics) that is explicitly caring and bears some similarities to this chapter, though without drawing on the above-mentioned literature on care ethics. Another paper in which a form of care ethics was featured prominently and specifically (though also without reference to the above-mentioned literature on care ethics) was that of Hyde & Karney (2001) who described an “ethic of caring” for the environment that involved caring attitudes and behaviors. Finally, Strobel et al. (2011) recently performed a systematic review of the literature on the twin topics of empathy and care, searching databases of research in education, social science, engineering, nursing, medicine and counseling. They indicated a variety of ways in which care is conceived in engineering and suggested that it shows encouraging prospects for care in engineering today.

2.2.3. CARE ETHICS AND SOCIAL JUSTICE

Care ethics, as implied earlier, is linked to social justice because it blurs the line perceived in conventional ethical thought between the public and the private, and effectively removes the distinction between what is moral and what is political. The public and private realms are recognized as equivalent in ways that have never really been considered before the advent of care ethics and this reveals political activity as essentially a moral endeavor and conversely moral activity as inherently political. As professor of business management, Thomas Hawk, explains, “Caring is a process that requires ongoing communication and conversation among all those impacted by the moral judgments in the full spectrum from personal relationships to societal relationships at the level of the nation” (Hawk 2011, p. 10). The ethics of the public and private realms are fundamentally intertwined and to continue viewing them as entirely separate and distinct only serves to perpetuate existing injustices by permitting different ethical standards for each. For example, in the case of free market economics, this has the effect of replacing ethical

choices (e.g., whom one should support financially) with choices that are seemingly value free (e.g., cheaper is better), but only illusory so because they benefit some (e.g., distant large-scale farms owned by corporations) at the expense and disadvantage of others (e.g., local small-scale farms owned by neighbors).

Since Tronto articulated this view of the distinction between public and private as a false dichotomy, others have attempted to integrate theories of justice with care ethics and/or to develop care ethics as a comprehensive ethical theory. While it is beyond the scope of this chapter to review all such attempts, it is helpful to consider a few prominent ones. Held (2006 p. 17) considers care ethics to be foundational to any moral theory: while care can occur in the absence of justice, there can be no justice without care because (1) every human life depends on the care of others from infancy through childhood, during times of illness, and in old age, and (2) without caring family relationships as a foundation, children would not survive and societies would not exist in which to make issues of justice even salient. In her view, justice is, however, a complementary and very important concept, both as it has traditionally been invoked in policy and law, and also in families and male-female relationships, where it has historically been neglected resulting in the unjust treatment of women. Professor of political science Daniel Engster (2007) similarly sees care ethics as “the heart of justice” and attempts to delineate “a minimal set of moral and political principles that apply to all people and societies regardless of how else they might choose to organized their private or public lives” (p. 4).

Perhaps the most directly pertinent theory of care ethics to social justice and humanitarian engineering is that of care ethicist and professor of philosophy Michael Slote (2007), who builds his argument on the importance of empathy for ethical caring using the term “empathic caring”.⁷

⁷ Given the applicability of Slote’s version of the ethics of care to social justice and humanitarian endeavors, the reader might wonder why I have not adopted it instead of Tronto’s framework for the analyses presented in this chapter. I have two reasons for this, one of which is pragmatic and the other philosophical. Pragmatically speaking, I find that Tronto’s framework provides a clearer and better scaffolded conceptualization of care ethics that is closer, for better or worse, to the way engineers think. It thus provides a better, more developmentally appropriate introduction to care ethics than Slote’s theory and even helps us see where conventional engineering mindsets might steer us wrong in our caring endeavors. From a philosophical point of view, I am reluctant to accept the notion in Slote’s (and for that matter, Noddings’) theory that humans have a lower level of responsibility of ethical caring for distant or lesser-known others than for those in close proximity. While there may be some truth to such a notion from the perspective of resource limitations, to say that international

Slote makes the distinction between *sympathy*, which is merely feeling sorry or bad for someone, and *empathy*, which is characterized by actually feeling what another person feels. He further makes a distinction—as supported by research in the field of psychology—between two types of empathy: projective empathy, in which one must deliberately project oneself into the situation of the other, and mediated associative empathy, which is more passive, receptive and reflexive. It is this latter form of empathy that is the ideal for empathic caring since it is more natural and altruistic while the former may be forced or contrived. Neither type of empathy, however, involves a merging of identities of the care-giver and care-receiver: empathic individuals always retain their own identities. However, through experience and the exercise of moral imagination, it is possible to develop skills of empathic caring that are effective for caring for distant others and that even enable predictive capabilities whereby one feels what another would feel in other potential situations.

2.3. CARE IN THE ENGINEERING PROFESSION

A brief look at the various roles played by the engineering profession is helpful in understanding where engineering is, where it is going, and the ways that care and concern for others can be, and in some ways already are, manifest in engineering. Mitcham & Munoz (2010), Lucena et al. (2010), and Riley (2008a) all offer perspectives on the history of engineering that inform the following subsections.

humanitarian caring is less important than caring for those locally in need seems to encourage an attitude of selfishness and tending one's own garden (Tronto 1993, p. 171) that would easily turn a blind eye to the impacts of one's actions on distant others. Such a position seems particularly problematic for non-human life and the ecosystem, much of which will always be distant and difficult to know in the way one can get to know people (at least with distant people one could move to a new region and make new friends, neighbors, and coworkers). Does this mean caring for the environment should always play second fiddle to caring for one's family or nation (e.g., through providing material or economic comforts)? How would matters of environmental pollution and sustainability be addressed? Slote admits that even the applicability of empathic caring to animals is complicated and daunting (Slote 2007, p. 19).

2.3.1. ENGINEERS AND THE MILITARY

According to Mitcham & Munoz (2010), the work of the first engineers was military in nature as it involved designing and operating fortifications and tactical devices such as draw bridges, siege engines and catapults. Even today, the ties of the engineering profession to the military run deep as indicated, for example, by the large number of engineers involved in defense-related industries (Bowen 2009; Riley, 2008a). While it could be argued that in a military context, care is manifest in efforts to defend against the threats of the enemy, care and compassion are not ideas easily associated with military endeavors. In contrast to the war-time efforts of Red Cross doctors and nurses, who aid the injured regardless of alliance, it seems naïve to imagine a group of impartial engineers tending to the water purification or transportation needs of soldiers on either side of the conflict. Indeed, this would probably be viewed as treasonous, perhaps because the purview of such engineering work is in meeting higher level needs and conveniences (see Mitcham & Munoz 2010), rather than basic needs associated with fundamental human rights.

In terms of Tronto's framework, we can only imagine the care ethics that engineers might manifest in military endeavors. In a world that glorifies violence and spends exorbitant amounts of money and resources on warfare and defense (see Bowen 2009), an ethics of care that promotes non-violent alternatives to conflict has surely never been attempted. For example, rather than building weapons for destruction or deterrence, engineers might be commissioned to build language translation mechanisms that facilitate dialog and understanding between neighboring communities and countries. Rather than building technologies for deception, manipulation and control, they might find novel ways to create openness and trust so that disagreements over competing interests could be better negotiated and resolved without resorting to violence. Perhaps even more directly, Bowen (2009) makes the case that more engineering skills and services could be far better utilized in addressing some of the major causes of war, such as energy supplies (e.g., by providing alternatives to oil and gas), and water resources (e.g., by using existing technologies to provide sanitation and safe drinking water for all).

Even within the context of military engineering and weapons building, there are opportunities for engineers to begin practicing care ethics. For example, as Bowen (2009) points out, the majority of the victims of engineered weapons, such as cluster munitions, are innocent people and often

children. Care ethics in this context might involve designing weapons that are capable of accurately discriminating between military and civilian targets, or that are difficult to use in ways that contravene international conventions and treaties.

2.3.2. ENGINEERS IN INDUSTRY, GOVERNMENT, AND COMMERCE

The Industrial Revolution created demand for professional engineers with a civilian focus for the design of machinery, irrigation & drainage systems, roads, dams, and related infrastructure (Mitcham & Munoz 2010). Coupled with industrial scale production came large-scale consumption, which has created even more opportunities for engineers across virtually all sectors of the economy not only in the primary “raw materials extraction” sector and the secondary “manufacturing” sector, but also in the tertiary “services” sector with jobs in such fields as consulting, information & communication technology, and even entertainment. Note, however, that the number of engineers and their roles in each of these sectors are limited by the size and developmental level of the economies of which they are a part. In regions where industrialization has not occurred (i.e., the so-called developing world), many of the benefits of engineering, as conventionally conceived, may be impossible to realize.

Looking at engineering through the lens of these economic sectors might give the impression that engineering talent tends to follow power and money; however, as Lucena et al. (2010, chapter 2) show, the reality is more complex. Engineers have indeed been involved in supporting imperialism by building machinery and infrastructure to facilitate the extraction of raw materials from colonial lands and subjugate indigenous people as slave laborers. However, engineers have also been involved in locating and extracting resources and building infrastructure in their own countries for the purpose of nation building and creating public works for the use and convenience of their fellow countrypeople. For many, the motivation to contribute to the common good has surely been a driving consideration, as evidenced by engineering attempts in early 20th century America to unify as a profession against the interests of corporate business for ostensibly altruistic purposes (Layton, 1986). Furthermore, even while some engineers were involved in colonial and nation-building efforts, some have been involved in arguably more philanthropic endeavors as will be described in the subsections to follow.

When we look at the economy from the perspective of ownership, we see that the public sector enjoys the talents of engineers working at many levels and in many areas of the government, from departments of defense, to environmental protection agencies, to electric power utilities at the national, regional, and municipal levels. In the private sector, engineers work for multitudes of companies and corporations or even freelance as consultants and contractors. However, in spite of this variety of employment opportunities, and unlike some of the more people-centered professions, such as medicine and law, engineering is not known to be a particularly caring profession. In fact, according to the findings of a study conducted by Harris Interactive in 2003 (see NAE 2008), the American public perceives engineers as being significantly less sensitive to societal concerns and less caring about the community than scientists. While there are logical reasons for engineering's poor public image, such as the fact that engineering work is often not conducted in physical or temporal proximity to the end user (Bowen 2009) and thus precludes the personal relationships that doctors enjoy with their patients, it is interesting to note that the idea of pro-bono work to aid those in need has historically not been part of the culture of engineering (Baum 1985).

Like engineering in military contexts, the idea of care and concern for others in civilian engineering employment is also somewhat hard to imagine. Perhaps this is due to the problem of engineering's complicity in a materialistic capitalist economy that tends to commodify even human relationships.⁸ Pantizidou & Nair's conception of design and problem solving as care, or Kardon's standard of care (see section 2.2.2 "Care Ethics in the Engineering Education Literature" above) might thus be adequate descriptions of care as presently instantiated in these sectors. In terms of Tronto's framework, the Integrity of Care (as a disposition) appears to need development in secular engineering employment. Engineers working in imperialist settings seem to need work on all stages of care, starting perhaps with improving attentiveness to needs other than their own. For engineers involved in public works and nation-building, consideration of care ethics might

⁸ Moriarty (2008) articulates this well as "[t]he problem with an economy in the grip of the capitalist "take" on reality is that everything becomes commodified and human relationships become purely functional and instrumental. An attitude of respect for persons becomes more and more difficult to maintain." (p. 58) and "...capitalism implicates engineering almost totally in its cycle of commodification, production and consumption." (p. 91). My gratitude to the anonymous reviewer who suggested the addition of this point.

point to deficiencies in attentiveness to the needs of the environment or to future generations who will be deprived of the opportunity to benefit from undepleted natural resources and unpolluted public lands.

2.3.3. ENGINEERS AS TECHNICAL VOLUNTEERS

Engineering roles in the non-profit sector over the past century have largely been limited to voluntary work performed under the auspices of technical societies, such as the American Society of Civil Engineers (ASCE) and the Institute of Electrical and Electronics Engineers (IEEE), as well as professional associations, such as the National Society of Professional Engineers (NSPE) and the National Council of Examiners for Engineering and Surveying (NCEES). The mission of such organizations is usually to serve the interests of the engineering discipline or profession, its members, and ideally, the public. For example, the IEEE, which is the world's largest professional association for the advancement of technology with over 320,000 members in 1997, indicated in its mission statement:

“The purpose of ... [our] activities is two fold: (1) to enhance the quality of life for all peoples through improved public awareness of the influences and applications of its technologies; and (2) to advance the standing of the engineering profession and its members.”⁹

While these goals are technically- and somewhat inwardly- (toward the profession) focused, they are clearly more altruistic than those of industry and business, which usually aim to serve only themselves and their shareholders. Indeed, a desire to be more outwardly- and societally-focused is reflected in the revised and updated IEEE Mission and Vision Statement, which today reads:

“IEEE's core purpose is to foster technological innovation and excellence for the benefit of humanity. IEEE will be essential to the global technical community and to technical professionals everywhere, and be universally recognized for the contributions of technology and of technical professionals in improving global conditions.”¹⁰

⁹ From a 1997 archived version of the IEEE website, About IEEE, “The IEEE Is ... Achieving Goals”. Retrieved 13 January, 2012 from http://web.archive.org/web/19970225053543/http://www.ieee.org/i3e_blb.html

¹⁰ IEEE Vision & Mission. Retrieved 13 January, 2012 from http://www.ieee.org/about/vision_mission.html

To the extent that mission statements are a reflection of the collective motives and practices of a profession, over the past decade IEEE has moved from merely promoting technology for enhancing quality of life via improved public awareness of technology to fostering innovation for the benefit of humanity. Similar statements can likely be found for other engineering organizations as well. Arguably, this broadening of focus away from the profession and away from technology for its own sake to technology for a larger purpose can be viewed as evidence of an increasingly caring profession. While one might question the magnitude of changes in practice to which these assertions actually lead, I am optimistic that articulating such goals is part of a process that helps bring more diversity of thought into engineering, which will in turn encourage further reflection and thereby progress toward effective change. In terms of Tronto's framework, perhaps here too Pantazidou & Nair's conceptions of design and problem solving as care and Kardon's standard of care (see Section 2.2.2 "Care Ethics in the Engineering Education Literature") are adequate descriptions of care as presently instantiated in this context, but there is also evidence of development of the Integrity of Care as shown by the increasing Attentiveness expressed by concern for a larger purpose.

2.3.4. ENGINEERS AS PHILANTHROPISTS

Since the early days of engineering as a profession, there have surely been individual engineers who have quietly found ways to contribute their time and skills to various humanitarian efforts. For example, engineers may have been involved as missionaries seeking to alleviate poverty, suffering, and excessive labor through the application of their engineering skills while simultaneously actively promoting their religious beliefs. There have also been a few individual engineers that have captured the attention of the media and government, such as Fred Cuny (Anderson 2000; Pritchard 1998) and Maurice Albertson, founder of the U.S. Peace Corps (Mitcham & Munoz 2010). However, engineering as a profession has only recently begun to seriously entertain the idea of such forms of altruism and caring. IEEE's revision of its mission and values is perhaps indicative of this.

Carl Mitcham identifies a movement of "idealistic activism" that started prior to the 1950's among scientists and engineers: exemplified by such organizations as the Pugwash Conferences

on Science and World Affairs and the Union of Concerned Scientists (Mitcham 2003; Mitcham & Munoz, 2010). However, the first engineering-specific organizations of this sort did not appear until the 1980's inspired by Médecins sans Frontières (MSF a.k.a., Doctors Without Borders), which was founded a decade earlier. Over the past 30 years, organizations with similar names and objectives, such as Ingénieurs sans Frontières (ISF), Engineers Without Borders (EWB), and Engineers for a Sustainable World (ESW), have emerged independently across the globe. Many of these organizations have recently joined an international network known as Engineers Without Borders International (EWB-I), which was co-founded in 2002 by the founder of Engineers Without Borders USA (EWB-USA).¹¹ EWB-I currently lists 32 member groups, 13 start-up groups, and 5 affiliated EWBs from across the globe. Another potentially large and recent endeavor is the founding of Engineers for Change (E4C) by the American Society of Mechanical Engineers (ASME) in collaboration with the IEEE, and EWB-USA. This online platform for collaboration and resource sharing brings together engineers, technologists, social scientists, non-governmental organizations (NGOs), local governments and community advocates on seven areas of interest: water, energy, health, structures, agriculture, sanitation, and information systems.¹² While the number of engineers involved in humanitarian engineering endeavors is probably not very large compared to the total number of practicing and matriculating engineers, it is rapidly growing. For example, EWB-USA, which incorporated in 2002 with 8 students and 1 professor, reports 8 years later as having 12,000 volunteers from over 180 student chapters and over 70 professional chapters. In 2010, they sent 1,297 students and 729 professionals to partner with 240 communities in 45 countries around the world.¹³

In terms of Tronto's framework, engineers working in philanthropic settings like those described above might have their hearts in the right place in being attentive to the needs of other and dispositionally oriented toward an Integrity of Care; however, at the risk of being overly critical, I must point out that the desire to care and the ability to do caring work are not the same. While the desire to care is normally an important prerequisite for choosing to give care, there is no

¹¹ See "Proposal to Establish EWB-Global", accessed 2 March, 2013 at <http://www.ewb-international.org/pdf/EWB-1%20Proposal%2004%20June%20-%20Final.pdf> and the CV of EWB-USA Founder, Bernard Amadei, accessed 13 January, 2012 at <http://www.ewb-usa.org/theme/library/about-ewb-usa/ewb-usa-board-Bernard-Amadei.pdf>

¹² Retrieved 30 March, 2012 from <https://www.engineeringforchange.org>

¹³ Retrieved 13 January, 2012 from <http://www.ewb-usa.org/about-ewb-usa/annual-reports>

guarantee that one's intentions are automatically achieved merely by the will to act. The attentiveness element of ethical caring demands sensitivity to the actual needs of the care-receiver rather than needs created or projected by the care-giver, and the responsiveness element demands a respect for the beliefs and wishes of the care-receiver that seems problematically neglected by proselytism, be it religiously motivated or driven by unconscious and unquestioned promotion of a particular economic system or ideology. The next section expands on issues such as these.

2.4. BARRIERS AND NEXT STEPS TO A MORE CARING ENGINEERING ¹⁴

A key problem faced by the practice of humanitarian engineering is that of doing more harm than good (Lucena et al. 2010; Schneider et al. 2009; VanderSteen 2008). A number of important issues that humanitarian engineers need to consider can be gleaned from the literature. As members of a profession that is easily characterized as being narrowly focused and unreflective, engineers are particularly at risk for repeating past mistakes made in the fields of international development and global health. One such potential mistake is the tendency to promote the exclusively top-down planning approaches decried by Easterly (2006), who's critique of "planners" is especially pertinent to engineers: "A Planner thinks he already knows the answers; he thinks of poverty as a technical engineering problem that his answers will solve" (Easterly 2006, p. 6). Easterly's portrayal of "searchers" sets the stage, I believe, for a better alternative: "A Searcher admits he doesn't know the answers in advance; he believes that poverty is a complicated tangle of political, social, historical, institutional, and technological factors."

Another issue of concern is the importance of being critical of one's motivations to help others and maintaining humility about one's ability to do so (Schneider et al. 2009; Lucena et al. 2010). Being invited to learn from and work with a community or to help amend injustices involves a very different mindset than that of charity work, which risks being paternalistic and even undesired by the recipient. If we are sincere in our desires to help and willing to do the work that effective caring involves, we must set aside our egos and desires to feel good about ourselves, and proceed with humility.

¹⁴ Portions of this section are adapted from a conference paper written by the author (see Campbell & Wilson 2011).

A third issue of concern is that engineers, trained with a narrow technical focus, are likely to be oblivious to the broader cultural, political, and economic contexts, such as neoliberalism¹⁵ and globalization, that have created the needs—real or perceived—they are stepping in to fill (Schneider et al. 2009; Lucena et al. 2010). The communities they wish to help, however, are more likely to be aware of these contexts and of the inequities that rich countries helped to create (Schneider et al. 2009) and thus may be skeptical of, or even hostile to offers of assistance. Engineers must be cognizant of these contexts and should call on the expertise of other disciplines, such as the humanities and social sciences (Lucena et al. 2010), to help them understand, appreciate, and incorporate these contexts into their work.

Related to this is the issue of insufficient organizational learning. Effective long term evaluation, as well as learning from past experience—both successes and failures—is essential and really only possible through cross disciplinary organizational understanding. While there is evidence of movement in the direction of improved accountability through self-reflection on problems due to technical, communication and cultural issues, little effort appears to be made toward understanding how systemic inequities may create patterns of failure across multiple projects (Riley 2008a). Hopefully the recent movement toward admitting and learning from failures in international development in general, and in humanitarian engineering organizations in particular,¹⁶ will enable and encourage broader reflection and promote accountability.

Accountability has also been identified as an issue of concern: Riley (2008a) points out that there is presently little accountability to the target communities by existing humanitarian engineering programs and organizations. This is also true of most NGOs in international development who tend to be more accountable to their donors than to their beneficiaries (HAP 2010). A final issue of concern is directed at student involvement in humanitarian engineering

¹⁵ Neoliberalism, defined as a “fanatical form of capitalism that places ultimate faith in private property, free markets, and free trade, privatizing industries and lifting any government protections on trade, the environment, labor, and social welfare” (Riley, 2008a, p. 7), is criticized as being responsible for increasing disparities in wealth and opportunity, exploiting labor and the ecosystem (Harvey 2005), and along with the prevailing culture of positivism in society, is even complicit in stripping education of its true value and meaning (Giroux 2011).

¹⁶ See EWB-Canada’s Admitting Failure website (<http://www.admittingfailure.com>) as well as the information & communication technology for development (ICT4D) community’s FailFaire conferences (<http://failfaire.org>).

work under the rubric of service learning, which has the potential to create exploitive relationships between privileged students and “developing” communities (Schneider et al. 2009) whereby students gain real-world experience, but communities end up with unworkable or short-lived solutions.

Humanitarian engineers must find ways to take responsibility, follow through, and follow up to avoid inadvertently taking advantage of these vulnerable populations they aspire to help. As Schneider et al. (2009) point out, altruistic motives must, at minimum, be transformed from mere sympathy to genuine empathy before any actions taken by well-meaning engineers will be of lasting benefit to the communities they wish to assist.

2.4.1. ETHICS OF CARE AS A GUIDING FRAMEWORK FOR SOCIAL JUSTICE

As section 2.3 “Care in the Engineering Profession” has shown, there is evidence that practicing and aspiring engineers are increasingly interested in creating more explicit opportunities to manifest care and concern for others in their work. The task before us then is to help engineers move beyond good intentions and contribute constructively, and however modestly, in their endeavors to save the world. As mentioned above, it is unfortunately all too easy to care about someone or something and yet be entirely ineffective in actually *caring for* the object of concern. Something more than concern and willingness to take action is needed. As Held (2007) aptly stated, “when benevolent concern crosses over into controlling domination, we need an *ethics* of care, not just care itself” [emphasis in original]. An ethics of care is similarly needed to ensure that care work performed meets the needs of others and that the needs are in fact accurately understood.

In terms of Tronto’s framework, looking across the whole of the engineering profession, we could say engineering appears to be in the first three phases: starting to be Attentive by recognizing the needs of others, becoming increasingly motivated to take Responsibility, and moving into the Competence phase of care. Effort must be made not to skip steps in Tronto’s framework by trying to enter the phase of Competence before that of Responsibility, as the issues of accountability mentioned above might suggest are occurring. What is needed, then, are means to help engineering

students, educators and practitioners to understand and apply care ethics in engineering contexts so that they can become better at

1. recognizing and understanding needs, their causes (e.g., neoliberalism—see footnote 15), and the possible effects/constraints associated with those causes.
2. taking an appropriate level of responsibility for addressing those needs (and for their causes)
3. performing the work of care in a competent manner, i.e., in a way that also addresses the underlying causes of those needs rather than just treating symptoms
4. working with the care-receivers at all project stages and reflecting on feedback as to the effectiveness of care-giving efforts
5. practicing a holistic “integrity of care” that strengthens and develops the quality of care engineers are capable of providing

Lucena et al. (2010) address many of these issues by promoting (a) active/contextual listening techniques that improve Attentiveness and Responsiveness, (b) self-reflection on motivations, which provides Integrity and improves both Responsibility and Competence, and (c) participatory techniques that engage care-receivers thus enabling Responsiveness and improving Competence. See Appendix B.2 and B.3 in this dissertation for brief introductions of active/contextual listening and participatory design techniques, respectively.

2.4.2. THE PROBLEM OF PATERNALISM AND HOW TO AVOID IT

In my view, Pantazidou and Nair’s conceptions of design and problem solving as care and Kardon’s standard of care (see section 2.2.2 “Care Ethics in the Engineering Education Literature”) represent important first steps toward understanding care ethics in engineering. However, these conceptualizations seem to lack the essential altruistic and interpersonal nature of care. Furthermore, while Tronto’s framework, upon which they build, is helpful in thinking about the ethics of care in engineering, there is something fundamentally paternalistic¹⁷ to it in the context of humanitarian engineering work since it seems to encourage, if not require, heroic care-givers

¹⁷ Tronto acknowledges paternalism as problematic (p. 145), but does not seem to offer any solutions or practical work-arounds. However, she does point out that at least through care ethics one can recognize and identify such issues and this is surely preferable to sole reliance on a moral theory that cannot.

and helpless care-receivers. With faith in technology and mindsets geared toward problem solving (Lucena et al. 2010), engineers are prone to adopting a hero mentality that at best is not helpful for community development work and at worst can be harmful. Engineering, if it is to be a conscientious agent of change for the better, rather than a blind tool that ultimately serves to perpetuate injustice, needs an ethic of care that addresses the problems of paternalism.

For the sake of comparison, an ethics of care that follows Tronto's framework in the field of medicine might seem reasonable and appropriate in many cases because the relationship between doctor and patient is inherently unbalanced by the relatively high level of education, experience, and skill possessed by the doctor. While a similar differential in education, experience, and skill might exist between an engineer and, say, a group of villagers, a key difference is that, except in the possible case of disaster recovery, the purpose of the humanitarian engineer is not to effect a one-time cure through the careful diagnosis and prescription of some temporary measure. Instead, the humanitarian engineer must understand the needs of the community and its resources, be they natural, technological, or human capability, and thereby catalyze ongoing and sustainable improvement in the community's quality of life in a way that is not only desired by the community, but also engages and integrally involves the community in its own development so that the improvement is continuous and self-sustaining long after the engineer departs. How then should engineers approach meeting the needs of others? Held (2007, p. 32) expresses great hope for care ethics because:

"Care has the capacity to shape new persons with ever more advanced understandings of culture and society and morality and ever more advanced abilities to live well and cooperatively with others."

One way to think about this issue is through Slote's (2007) notion of empathic caring and the idea of mediated associative empathy that was introduced earlier in section 2.2.3 "Care Ethics and Social Justice". This conception of empathy encourages the respect and autonomy necessary for limiting paternalistic actions on the part of the care-giver.

In the interest of building on Tronto's framework, rather than adopting Slotes' theory (see my reasons for not doing so in footnote 7, section 2.2.3), I find it helpful to incorporate a concept

known as the I-Thou relation ¹⁸ as presented by philosopher Hans Georg Gadamer (2004, p. 352-255), who describes three possible modes in which people can choose to relate to others. The first mode involves an objectifying attitude toward the other that is dehumanizing and treats the other as merely a means to an end. This is not unlike the way a detached scientist might regard a research subject whom they value only as a data source. The second mode acknowledges the other as a person, but is self-oriented and paternalistic, viewing the other as one inferior through a mind closed to learning about the other. This is not unlike the way a knowledgeable doctor or teacher might condescendingly regard a patient or student they have evaluated, since the expert knows best and the other is deficient by virtue of his or her role as patient or student. True dialog and reciprocal communication in both of these modes of interacting with others is impossible because the other is not viewed as possessing a perspective worthy of learning about through open dialogue. In Gadamer's third mode of relating, the other is viewed as an equal with whom open, respectful, bi-directional communication is possible. This is a reciprocal and honest relationship not unlike that of friends or colleagues.

If truly ethical caring is to occur between an engineer and those he or she is hoping to help, then it is only this third mode of a care-giver relating to a care-receiver that can result in effective action because only then will true and effective Attentiveness and Responsiveness be possible. Any other way of relating to care-receivers risks (a) projecting needs on them instead of being open and attentive, and (b) paternalism and creating dependency rather than providing ethically competent care. We must be careful not to cross the line between care and paternalism, or between caring too much for ourselves and thereby creating unintended risks of exploitation. To overcome this problem, we must make effort to relate to those we might wish to help using Gadamer's third mode through mindsets of equality, humility, and respect.

¹⁸ Note that Bowen (2009) also employed a variation of the I-Thou concept (though based on Martin Buber's original conception), which, while useful for discussing issues of proximity, does little to help with the problem of paternalism.

2.4.3. ENGINEERS AS HUMANIZING ACTIVISTS

If we are genuine in our desire to help, we must be willing to uncover and understand real needs and their causes, take responsibility, perform the work of meeting the needs, and solicit, accept and learn from feedback provided. This will involve humility and patience as we learn from other cultures and societies. One thing we in the global North should do is stop viewing those in the global South as “less than” (Schneider et al. 2009) and instead look at those in the so-called developing world as noble and intrinsically valuable people from whom we could probably learn a thing or two about simplicity, efficiency (i.e., the ability to do much with few resources), generosity, family values, and spirituality.

In the area of information and communication for development (ICT4D), there is a growing awareness of the need for a new view of poverty (Heeks 2008) and constructive approaches to dealing with it that are enabling of human capacity rather than dependency-creating, as welfare and charity can often become. Indeed, Heeks describes a progression in the ICT4D community as following that of the appropriate technology movement of the 1970’s: a progression from innovation *for* the poor (pro-poor) to innovation *with* the poor (para-poor) to innovation *by* the poor themselves (per-poor). While Heeks does not go this far, I contend that the role of the humanitarian engineer might be better viewed as that of a builder not of hardware, software, or infrastructure, but of human capacity. The views of Paulo Freire (2000) seem remarkably appropriate here with regard to the humanizing and dialogical relationship he admonishes those in leadership to establish in liberating the poor from their condition. Engineers desiring to work in humanitarian engineering might do well using techniques of Freirean critical pedagogy in order to first become aware of their own roles and complicity in the power relationships that create and maintain poverty in the global South (see Riley 2008b for an example of what critical pedagogies might look like in an engineering ethics course). Once these issues are understood, aspiring humanitarian engineers can begin working on ways to improve social justice both from home through their various social, political, and/or religious affiliations, and in the field by catalyzing and providing support for indigenous grass roots solutions to social problems.

2.5. CONCLUSIONS

In this chapter I have introduced the ethics of care as a guiding framework for the engineering profession in achieving its noble aspirations to save the world. I have examined care ethics in the various traditional and emerging purviews of engineering, and discussed barriers to a socially just humanitarian engineering practice. Finally, I have described a way to overcome what I perceive as a key problem for ethical caring in humanitarian engineering, that of paternalism.

One contribution of this chapter has thus been to identify humanitarian engineering as providing an important pedagogical tool for incorporating care as a missing dimension to engineering education. This tool, if used wisely, can enable engineering practice to advance rather than impede social justice.

In summary, I believe the ethic of care needed in engineering to address issues of social justice can be described as promoting altruism, humility, cooperation, reflection/action (i.e., Freirean praxis), and concern with addressing the non-technical root causes of problems rather than simply treating symptoms with technical fixes.

Chapter 3. Ethical Attentiveness in Engineering: Exploring How Knowledge of a Humanitarian Disaster Affected Undergraduate Student Design Thinking

This chapter begins the empirical exploration, examining the first of three humanitarian/social justice contexts: natural disaster prevention. It is comprised of an unpublished manuscript¹ that looks at the ways in which students in 2006 said their knowledge of Hurricane Katrina (and its impact on New Orleans) influenced their design thinking on a river retaining wall design task. It builds on the previous chapter by adopting and developing the first of Tronto's elements of care ethics, Attentiveness, in an engineering context. It addresses the first part of the second research question (RQ2/RQ2-A) as well as a portion of the third research question (RQ3).

¹ Campbell, R. C., Yasuhara, K., Atman, C. J. (2016). Ethical Attentiveness in Engineering: Exploring How Knowledge of a Humanitarian Disaster Affected Undergraduate Student Design Thinking. Manuscript in preparation.

3.1. INTRODUCTION

Tronto's first moral element of care, *Attentiveness* (c.f. caring about), is the focus of analysis in this chapter. Care-ethical attentiveness involves awareness of others and their needs, and counts neglect or even ignorance (be it willful or inadvertently habitual) as moral failings. As an example, Tronto describes the failure of many wealthy people in industrialized countries to notice, in spite of worldwide information & communication technology and diverse media coverage, how "activities spurred by a global capitalist system result in the starvation of thousands" and encourage human trafficking and exploitation (p. 128). Given the prevalent relationship between engineering and the capitalist economy, this example may have serious implications for engineering. However, analysis of such broad and far-reaching considerations are outside the scope of this chapter.² However, examples illustrating Attentiveness that are closer to the traditional purview of engineering work can be found in many real world occurrences, such as the 2010 explosion of BP's (formerly British Petroleum) Deepwater Horizon oil drilling rig, which continues to impact people and ecosystems in and around the U.S. Gulf Coast (see Fikes, Renfro, & McCormick 2015), or the 2005 flooding of New Orleans that resulted from money-saving engineering design decisions of the US Army Corps of Engineers (see Rogers, Kemp, Bosworth, & Seed 2015 or Roberston & Schwartz 2015).

Attentiveness as an ethical imperative (i.e., that we should be attentive to the needs of others) provides an important perspective that is otherwise easy to miss: unethical behavior can occur out of ignorance that can be (a) intentional and willful (i.e., we can chose to ignore the needs of others), or (b) unintentionally created by habits and even social systems/structures (e.g., in spite of the abolition of slavery, racism in various forms has persisted in the U.S. for generations). Furthermore, ignorance that started out as unintentional can even become intentionally neglected by those with the power to effect change, especially by those who feel they stand to lose something. While accidental inattentiveness would certainly be less wrong than intentionally ignoring the legitimate needs of others (and I acknowledge here the value of consulting other ethical theories for help with clarifying and ranking objective needs), care ethics mandates that we must always be open and

² See, for example, the growing body of literature on engineering and social justice (e.g., see Riley 2008; Baillie, Pawley, & Riley 2011; Lucena 2013).

exerting ourselves to minimize the possibilities of accidental inattentiveness by actively striving to listen and stay sensitive to others and their needs. When applying this idea to engineering, it is easy to see that, from a care ethics perspective, engineers who are trained to simplify and decontextualize their work from people and their needs, as well as from the ecosystem and its needs, will not find it easy to perform their jobs ethically. Care ethics thus provides principled moral reasoning for widening the engineers' breadth of thinking, and Attentiveness provides a logical starting point in doing so.

3.2. DATA AND METHODS³

This chapter begins to address the dissertation's second research question (RQ2), which read: In terms of care ethics, how do students in traditional engineering programs respond to problems of humanitarian or social justice nature? Here, I focus on the first of Tronto's moral elements of care: Attentiveness. While the data analyzed in this chapter was not originally collected with Tronto's framework explicitly in mind, her phases/elements of care have value in interpreting and assessing student responses. The specific sub-question driving this work (RQ2-A) can be articulated as follows: ***How do students exhibit Attentiveness ("caring about") in the context of natural disaster prevention?*** At the end of this chapter, I also explore some of its associated implications (RQ3), e.g., on teaching and learning engineering, further educational research, and engineering ethics including suggestions for educational policy and the practice of engineering.

To address these questions, I conducted a qualitative study on a subset of data from the Center for the Advancement of Engineering Education's (CAEE) Academic Pathways Study (APS). As described in the CAEE final report (Atman, et al. 2010) and further detailed in the CAEE Technical Report CAEE-TR-09-03 (Sheppard, et al. 2009), a broad and diverse selection of forty undergraduate students at each of four U.S. institutions was surveyed, interviewed, and observed throughout the course of their four years of undergraduate education. In the first and third years of this study, these students performed a ten-minute design-scoping task that read, *Over the summer the Midwest experienced massive flooding of the Mississippi River. What factors would you take*

³ This section contains material adapted from Campbell, Yasuhara, Atman, & Sheppard (2012).

into account in designing a retaining wall system for the Mississippi? Interviewers read the above design task question aloud and provided it typed on an otherwise blank page. Students had 10 minutes to think about and write their responses. In the third year (spring of 2006), upon completion of the design task, the students were then asked to reflect on their design task responses using the interview protocol summarized in Table 3.

In this chapter, my analysis focuses on student responses that addressed Q8 (highlighted in the table), which asks about the influence that Hurricane Katrina might have had on their design task responses. Specifically, the interview question associated with the data analyzed in this chapter asked, *Did what you know about [Hurricane Katrina] affect how you approached the Mississippi flooding activity today? If so, please describe.* Note that Hurricane Katrina struck land in August of 2005 and that its aftermath in New Orleans and surrounding areas of the Gulf Coast had been in the news for the eight to nine months prior to these interviews.

Due to time constraints during data collection, a branched interview protocol was used, resulting in a subset of interviewees who were not asked the Katrina-related questions (Q7&8). Select details of the protocol are described briefly in Section 3.5 and the full branched protocol is available in Sheppard et al. (2009, p. 204-207). In the sample of 124 interviews conducted at four universities across the United States, 73 transcripts contained responses indicating influences of Hurricane Katrina knowledge on design task responses. Of these, 20 interviews included spontaneous (i.e., unsolicited) mentions of Hurricane Katrina, 7 of which were later prompted by the interview protocol questions (Q7&8) for further discussion. Commensurate with my methodological approach (described in Section 3.2.1 below), any responses that were pertinent to Q8 were utilized in this study regardless of where in the transcript they might have occurred. I thus analyzed all available data pertinent to *if* (i.e., whether) knowledge of Hurricane Katrina affect design task responses and if so, *how* (i.e., in what ways) did it do so.

Table 3. Summary of Protocol from the Year 3 Design Task and Post-Task Interview

Question #	Question Text
1	Over the summer the Midwest experienced massive flooding of the Mississippi River. What factors would you take into account in designing a retaining wall system for the Mississippi? [10-minute written design task]
2	What questions came to your mind as you were brainstorming your list?
3	Take a look at both the response you just wrote today and your response from two years ago. What similarities and differences do you notice between the two responses?
4	You've told me a little about how your responses are similar or different. How about how you came up with them? Consider how you thought about the activity and how you came up with the factors you wrote down, both today and two years ago. What similarities and differences do you notice?
5	Have you had any past experiences that helped you do the written activity? (If so, please describe.)
6	Have you had any educational experiences that helped you do this activity? (If so, please describe.)
7	How familiar are you with Hurricane Katrina and the flooding in New Orleans? Could you tell me what you know about these events?
8	Did what you know about these events affect how you approached the Mississippi flooding activity today? (If so, please describe.)

Table 4 summarizes the demographics of the 73 students from the 4 schools whose responses provide the data for this analysis. In recruiting study participants, diversity was a major objective (see Sheppard, et al. 2009, p. 17), so student groups that are traditionally underrepresented in engineering, such as women and racial/ethnic minorities, were intentionally oversampled. In terms of sex, 38% of the study participants were female—significantly higher than the approximately 20% in the sampled population. The degree of racial/ethnic diversity in the sample is representative of the combined demographics of the analyzed institutions' enrollments, and thus includes significant numbers of Black / African American, and Asian / Asian American students. In terms of citizenship, 22% of the study participants were not U.S. citizens. With regard to academic major, over 12 different STEM majors were represented, including 10 distinct engineering disciplines, with most participants majoring in either Chemical Engineering, Computer Science/Engineering, Electrical Engineering, or Mechanical Engineering.

Table 4. Demographic Summary of the 73 Interviewees

Demographic	Value	# of Participants
Sex	Female	28
	Male	45
Institution	Large Public University	25
	Suburban Private University	12
	Technical Public Institution	16
	Urban Private University	20
Race/ethnicity	African American / Black	15
	Asian American / Asian	12
	Mexican American / Mexican	5
	Multi-racial	6
	Other	4
	White / Caucasian	31
Citizenship	International	16
	United States	57
Major*	Aeronautical/Astronautical Engineering	3
	Bioengineering	1
	Chemical Engineering	11
	Civil Engineering and/or Environmental Engineering	4
	Computer Engineering (5), Computer Science (6), and Systems & Computer Science (5)	16
	Electrical Engineering	11
	Industrial Engineering	2
	Mechanical Engineering	15
	Metallurgical/Materials Engineering	2
	Petroleum Engineering	3
	Physics and/or Engineering Physics	2
	Technical Communication	1
Undeclared and Engineering (unspecified)	2	

* First majors are indicated here. Second majors were also indicated by 5 participants and included History, Informatics, Math (2 students), and Spanish.

3.2.1. ANALYSIS METHODS

Given the qualitative nature of the data and the exploratory and value-laden nature of my research question, I performed two layers of analysis. The first layer was descriptive and “close to the data” with a minimum of conscious interpretation. The second layer was explicitly interpretive, applying a care ethics lens via an operationalization of Attentiveness explained in a subsection below. Consistent with accepted practices in qualitative research for ensuring methodological soundness, I provide here a summary of my specific analysis approach to make the research context and process of the work transparent. This enables the reader to assess the “trustworthiness and authenticity” (Creswell 2000) of the work, by providing evidence of its credibility, dependability, and confirmability (qualitative analogues to the quantitative notions of internal validity, reliability, and objectivity, respectively) (Lincoln & Guba 1985, p. 189), as well as its transferability (the analog to quantitative notions of external validity and generalizability).

3.2.1a. *Descriptive Coding*

The first layer of analysis followed a descriptive approach borrowing aspects of phenomenography⁴ in order to capture the breadth and diversity of responses. Note that I did not attempt to produce a phenomenography in this research, but many of its aspect were used to guide the first layer of analysis, including:

- taking participant self-reports of experiences as the object of study
- utilizing entire transcripts as the corpus for analysis rather than just the responses to the protocol question of interest
- providing a descriptive coverage of the entire space of responses rather than just focusing on the most common responses⁵

⁴ For more information on phenomenography, see primary source documents Marton & Booth (1997) and Booth (1997). Also, Case & Light (2011) provide an introduction to it in their paper outlining a selection of qualitative methodologies that are “promising but as yet not well represented in engineering education research.” Examples of phenomenography in use in engineering education can be found in: Mann et al. (2007), who used it to study student conceptions of sustainable design; Calvo & Ellis (2010), who used it to study student conceptions of tutor and automated feedback in professional writing; and Zoltowski et al. (2011, 2012), who used it to examine student conceptions of human-centered design.

⁵ This is in contrast to the better-known phenomenology, which attempts to identify the common or essential experience of a phenomenon, and would thus be prone to neglecting minority views.

- utilizing a diverse sample of engineering students as study participants (see Table 4 above)
- striving for parsimony and logic in the resultant system of categories
- providing examination of relationships among the categories

Thus, while the focus of this analysis was on responses to Q8 (i.e., whether and how knowledge of Katrina affected design task responses), initial coding was performed by reading the entire post-task interview transcripts, tagging each protocol question asked (for subsequent navigational purposes), and then inductively coding (i.e., without any a priori codes) all Katrina-related responses, regardless of where in the transcript they may have occurred.⁶ ATLAS.ti qualitative data analysis software was used to facilitate the process of thematic analysis, where transcripts were inductively coded for if (i.e., whether) knowledge of Katrina influenced design task responses, and if so, how (i.e., in what ways) they did so. This was an iterative process of re-reading and evaluating the applicability of the passages to the codes, and included renaming and redefining some codes, as well as revising or re-assigning different codes to some of the passages. As a part of this process of code definition/application, I met frequently with another researcher to discuss the names, definitions, and applications of the low-level, grounded codes,⁷ as well as the higher-level categories. Furthermore, in the early stages of the analysis, I and the other researcher held regular conference calls with other members of a related project team to report out and get feedback on the analysis in general and more specifically on the higher-level categories. Once I felt the code definitions and applications were relatively stable, I developed coding guidelines for use with another coder to further refine and validate the coding scheme. I then grouped these inductively derived codes into higher-level categories. To facilitate reporting sub-themes within these categories, I then printed the quotes for each category and performed a card-sort to group them into themes. The final set of low-level, grounded codes and higher level categories are detailed in Appendix D and described briefly below:

⁶ This decision, made in accordance with the phenomenographic principle of utilizing the complete interview transcript, also served to maximize available data by allowing the inclusion of pertinent data that happened to fall outside the direct response to the prompted interview question. In the reported analyses, such responses were in the minority (20 out of 73) and were interpreted and utilized judiciously.

⁷ Grounded codes are “closer to the data” in that they are assigned with minimal interpretation of data and are given names that match or closely resemble relevant wording in the coded data where possible.

Coding for If/Whether Katrina Knowledge Influenced Design Tasks

The final coding scheme for if (i.e., whether) Katrina knowledge influenced approaches to design tasks consisted of 3 codes: yes, no, and ambiguous. As detailed in Appendix D.1, ultimately, one of these three codes was applied to each transcript that contained mention of Hurricane Katrina. A second coder was used in this coding scheme to independently verify random selections⁸ of transcripts. Differences were negotiated to consensus, and, based on this, the remaining transcripts were screened for any possibly ambiguous/contentious responses, which were then similarly coded and negotiated to consensus. The final applications of codes in this coding scheme were mutually exclusive for each transcript.

Coding for How (i.e., Ways in Which) Katrina Knowledge Influenced Design Tasks

The final coding scheme for ways in which Katrina knowledge influenced approaches to design tasks consisted of 4 categories. While these categories were built upon 37 low-level, grounded codes that I initially identified (in consultation with another researcher), they were ultimately given stand-alone definitions, as detailed in Appendix D.2. The grounded codes thus served as an intermediary to the final categories and were used as possible examples/illustrations of their respective category. Using these categories as codes, a second coder independently verified each applicable transcript and all differences were negotiated to consensus. Given the nature of responses, more than one category may have applied to any given passage or quotation, thus applications of codes in this coding scheme were not mutually exclusive.

In the development of these categories, a number of ways of organizing and discussing the empirically derived codes are possible and many were explored, such as grouping by technical vs. non-technical considerations, by physical or conceptual proximity to the retaining wall (see Kilgore et al., 2007), and by types of stakeholders implied. However, each of these classifications proved problematic or undesirable in some way. Specifically, we found that grouping by technical / non-technical considerations provided too coarse a classification that lost some of the richness of

⁸ These transcripts were chosen randomly but within specific demographics to ensure proportional female/male representation across all four institutions.

the data and ran the risk of perpetuating or implicitly endorsing the value hierarchy that persists in engineering of the “hard,” important technical considerations versus the “soft,” less important non-technical considerations (see Leydens & Lucena 2007, and c.f. “mindsets in engineering” in Riley 2008). Grouping by physical or conceptual proximity to the retaining wall proved difficult for many codes that are either ambiguous or lie at the boundaries between categories, and this approach did not facilitate discussion of the inter-relations between considerations that many students identified. Grouping by stakeholders required more interpretation of participants’ words than we were comfortable performing with this data, and many codes indicated multiple stakeholders. Ultimately, the most natural and parsimonious organization proved to be grouping by four broad Areas of Concern, as presented in the Results section (specifically, see Table 6). Note that the development of these categories was not driven by consideration of any framework for care ethics, but by an attempt to privilege the voices of the participants and describe them as accurately and comprehensively as possible.

3.2.1b. Operationalizing Care-ethical Attentiveness for Discussion/Interpretation

After completing the first layer of analysis via the coding passes described above, I performed another, more interpretive layer of analysis, the outcome of which appears in the Discussion & Interpretation section (Section 3.4) below. This layer of the analysis was also performed using ATLAS.ti qualitative analysis software, building on the “how” code applications but incorporating additional context from the full interviews as appropriate. Here, care-ethical attentiveness was ultimately operationalized in terms of passages citing:

- 1) both others & needs
- 2) only needs
- 3) only others
- 4) neither others nor needs

Passages citing *both others & needs* included explicit indications of awareness of both specific others and their needs. Passages citing *only needs* included explicit indications of awareness of specific needs held by individuals, groups, institutions or entities, e.g., human, animal, plant, river, ecosystem, though mention of the “other” in this case would be at most vague or implied. Passages

citing *only others* included explicit indications of awareness of specific individuals, groups, institutions or entities, e.g., human, animal, plant, river, ecosystem, who were in need, though the need in this case would be at most vague or implied. Passages citing *neither needs nor others* were those indicating neither explicit awareness of need nor of specific individuals, groups, institutions or entities (e.g., human, animal, plant, river, ecosystem) who were in need. Further details on this second layer of analysis are given in Appendix D.3.

Note that, for the purpose of this work, I avoid the terms “inattentive” and “not attentive” because they require making value judgments based on the intents of participants, and the data does not provide enough information to make such assessments. For example, inattentiveness in Tronto’s view of care ethics involves ignoring others and/or their needs either consciously/intentionally or unconsciously due to learned habits or cultural blind spots. My use of the phrase “citing neither others nor needs” does not carry such meaning and instead indicates only that the given passage lacks evidence of awareness of others and their needs. I do not attempt to make claims about participant intentions, and thus am limited to reasonable inferences based on what was said in the interviews.

3.2.1c. Selecting Quotations

In selecting quotations for inclusion in this chapter to represent the categories and any emergent sub-themes within the categories, the following criteria were used, presented here roughly in order of priority based on practical constraints. The selected quote should:

- a. be clearly illustrative of the intended theme or code.
- b. be easy for the reader to understand without excessive additional contextual explanation to situate and clarify the interviewees meaning (where possible).
- c. illustrate the breadth of any nuanced sub-themes within a category.
- d. give voice to a variety of interviewees and thus not privilege some perspectives over others.

When selecting quotations to illustrate care-ethical attentiveness in this chapter, criteria “a”, “b”, and “d” above were similarly used to the extent possible with the data. For item “b” this particularly was challenging because additional context was often required for meaningful

understanding of the ideas. Item “c” was generally not followed in this second layer of the analysis because it made more sense to present representative and theoretically generative examples than to attempt exhaustive coverage of ideas that, while present in the data, were not explicitly part of the original data collection objectives. This is also the reason I report the outcomes of the second layer of the analysis within the Discussion & Interpretation section.

3.3. RESULTS OF DESCRIPTIVE CODING

The post-task interview question analyzed in this chapter was Q8: “Did what you know about [Hurricane Katrina] affect how you approached the Mississippi flooding activity today?” I found indications of both *if* and *how* Katrina affected the design task in the students’ responses. Thus, the findings are discussed below under the following groupings:

1. Indications of *if* (i.e., whether) knowledge of Katrina affected their design tasks
2. Indications of *how* (i.e., in what ways) knowledge of Katrina affected their design tasks (where such information was provided)

When discussing each of these groupings, a summary of the low-level grounded codes and any higher-level categories are first presented, followed by example quotations that represent each code. Quotations are numbered sequentially for ease of reference. Note that more than one grouping (i.e., *if* or *how*) and more than one code/category within those grouping may apply to any given quotation, and that quotations are often presented with some of the accompanying context to allow the reader to better understand the code definitions used.

3.3.1. DID KNOWLEDGE OF KATRINA AFFECT RESPONSES?

Table 5 indicates *if* (i.e., whether) knowledge of Hurricane Katrina affected student thinking. The first code listed in the table (Yes) is comprised of affirmative responses indicating that Katrina affected performance of the design task. Degree or qualifications of influence are not distinguished, thus this code applies to responses that are confidently affirmative (e.g., “Oh yes”), unqualified affirmative (e.g., “Yes”), and qualified affirmative (e.g., “A little” and “I think so”). The second code (Ambiguous/Maybe) contains responses that are unclear or “on the fence” in

indicating whether or not Katrina knowledge affected design task responses. Note that this ambiguity differs from connotations of both limitation and firmness/softness. The third code (No) is comprised of responses indicating that knowledge of Katrina did not affect their design task responses. Again, degree or qualifications of influence are not distinguished, thus this code applies to responses that are confidently negative (e.g., “Definitely not”), unqualified negative (e.g., “No”), and qualified negative (e.g., “Not really” and “I don't think so”). These three codes are mutually exclusive in that each interview was coded with one and only one of these codes as described in the codebook (see Appendix D.1).

Table 5. Indications of If (i.e., whether) Knowledge of Hurricane Katrina Affected Design Task Responses

Code†	Reported effect of Katrina knowledge	Number of interviewees
Yes	affected performance of the design task	43
Ambiguous / Maybe	was ambiguous with respect to influence on the design task	2
No	did <u>not</u> affect performance of the design task	28

† These codes are mutually exclusive (see codebook in Appendix D.1).

Illustrations of the “Yes” Code

Noting that while degree or qualifications of positive influence were not distinguished in the application of this code, I have grouped them loosely based on such distinctions to serve as an organizational aid in describing them below. For example, some students were particularly confident in their affirmative responses to Q8, as exemplified by this quotation:

“Yeah, I think definitely, because I thought about like what’s – what’s the reason that caused the flooding...”
—Amanda (1)

Some responses to Q8 were less decisively affirmative than the above but still indicated that knowledge of Katrina had some limited influence. The following quotes from Johnny and Samantha are illustrative of this:

“So, yeah, just relate it back to Hurricane Katrina, um, it does help a little, because you know it’s realistic to become concerned with [such severe flooding].” —Johnny (2)

“I guess I did kind of think about that.” —Samantha (3)

Similarly, some responses to Q8 indicated that while Katrina knowledge had some influence, that influence was limited. The following quote from Tarja is an example:

“It crossed my mind, but it – I guess I don’t know any – much about the engineering behind rebuilding New Orleans, so it didn’t come up too much.” —Tarja (4)

Some students even appeared to be somewhat dismissive of the influence that Katrina knowledge had on their responses, such as the following quotes by Brian and Austin:

“Uh, I guess I talked about how the walls or the system would need to be better around where people were living, but that’s really it, just trying to protect human life more... I didn’t really take that into a huge account.” —Brian (5)

“Um, I think really not too much. Um, I mean, yeah, so I mean both times you look at possibilities of, you know, how much the water could rise or, I guess, any other damage that could happen to the wall. It seems like a pretty obvious consideration. I mean you don’t need a hurricane to tell you that if you’re building – I mean if you’re building a retaining wall you want to look at, you know, possible water rise, it seems. That’s kind of the purpose. I don’t think – yeah, I mean...” —Austin (6)

As indicated in Table 3 (Section 3.2 above), prior to being asked the protocol questions about Katrina (Q7&8), many of the students (approximately 30) were presented with their design task responses from Year 1 and asked in Q3 & Q4 to compare them with what they had just completed. This may have helped some students to recognize the influence that Katrina had on their thinking. In fact, in response to Q4 (i.e., compare similarities and differences in approach to the design task between Year 1 and Year 3), two students spontaneously indicated that Katrina affected their responses. Jesse clearly stated the influence of his awareness of Katrina:

“Um, well, I think similarities, just visualizing just an arbitrary river with the flood and kind of what a wall would look like. I think a major difference was that before last time and this time, like Katrina happened, and so there’s like actual flooding and like these levies broke, and – and, you know, caused all this water to flow into a city, and so just the consequences of that, just seeing that not firsthand but through TV. You know, that definitely had an impact on what I thought.” —Jesse (7)

When he was later asked the protocol question (Q8, i.e., did knowledge of Katrina affect design task responses), Jesse reiterated his above assertion.⁹ Other students, now in response to Q8, provided further reflection and comparison of their Year 1 and Year 3 design tasks as influenced by their knowledge of Katrina. Justin, for example, was at first skeptical of an influence, but then on reflection realized and articulated that influence:¹⁰

“I’d say at most it sounded similar, but, um – yeah, so it did affect how I approached this activity, the second response, because, I mean, my first answer is who needs to be protected from the floods, and before I never – I never really talked about the people involved. In my earlier response I didn’t talk about the people involved, but in the second response I did talk about people.” —Justin (8)

Illustrations of the “Ambiguous/Maybe” Code

In this data set, only 2 instances of the Ambiguous/Maybe code were found and they are summarized here. In one case, the participant expressed unresolved equivocation in their self-report: first indicating yes, followed by doubt that it influenced the design task to which they were responding. The other case was an unprompted mention of Katrina in which the student appeared to be using the disaster as a rhetorical example and it was not clear whether or not Katrina knowledge actually influenced their design task response. Since this participant was not later asked the Katrina questions (Q7&8) from the interview protocol, this instance was coded ambiguous.

Illustrations of the “No” Code

Prior to being asked Q8 (i.e., did knowledge of Katrina affect design task responses), the students were primed by the interviewer with Q7 (i.e., what do you know about Hurricane Katrina and the flooding in New Orleans). In spite of being “warmed up” by talking about what they knew about Katrina, most negative responses to Q8 were short, direct statements of “no” without

⁹ The quote for the other student, Mimi, who was never asked the protocol question but spontaneously mentioned Katrina, will be discussed later in Section 3.3.2a.

¹⁰ An alternative explanation is that he was led by the interview protocol to attribute his consideration of people to knowledge of Katrina. However, either way, something caused him to consider the protection of people where he did not do so before. Analysis of themes such as consideration of people will be described in Section 3.3.2a.

explication (and without further prompting by the interviewer). Some students, however, provided additional insights as to why Katrina knowledge had no effect, as exemplified by Michael:

“No, not at all. Probably because I just didn’t think of it the same at all. I guess I could have. I mean I see the link now...”
—Michael (9)

3.3.2. WAYS IN WHICH KATRINA AFFECTED RESPONSES

Table 6 indicates *how* (i.e., in what ways) knowledge of Katrina affected responses to the written design activity. For the students who provided such indications, Katrina caused them to consider issues like human safety/protection, impacts on the ecosystem, cost-benefit analysis, and the importance of technical design criteria, such as wall strength and dimensions. The complete list of empirically derived or “grounded” codes are indicated in the Examples column of Table 6 is grouped by the higher-level categories I refer to as *areas of concern*. These are labeled “People/Society”, “Natural Environment”, “Designed Artifact”, and “Aspects of Design Approaches.” It is these categories¹¹ that will be used below to present the findings of the analysis.

The total raw number of instances of “grounded” code applications was 145, which is much higher than the number of participants because most participants indicated multiple ways in which their Katrina knowledge influenced their design tasks and may have indicated the same idea(s) more than once. Of the 43 participants in Table 5 who said their knowledge of Katrina influenced their design tasks, 36 gave clear indications of how it did so and 7 were ambiguous in this regard. The total number of distinct ways indicated by each student varied from 1 to 21, with a median value of 3. Statistical analyses and comparison are beyond the scope of this work, but preliminary findings and ideas are described later as future work (see Section 3.6.2). Graphically, Figure 3 provides a by-participant overview of the variation in type and quantity of codes applied in each of the four areas of concern, and Figure 4 provides an aggregate indication of the breadth of considerations, summarizing the number of different areas of concern mentioned by all participants. Figure 5 expands on Figure 4, showing the breadth of considerations disaggregated

¹¹ A number of ways of organizing and discussing the codes presented in Table 6 are possible, and many were explored. See “Coding for How...” Discussion in Section 3.2.1a for more on this matter.

by every possible combination of area of concern, revealing that, for those for whom Katrina-knowledge prompted only one design consideration, the most common areas of concern were People/Society followed by Aspects of Design Approaches.

Table 6. Indications of How (i.e., ways in which) Knowledge of Hurricane Katrina Affected Design Task Responses

Category / Area of Concern*	Description indications that Katrina knowledge prompted consideration of ...	Examples (Grounded Codes)	Number of Interviewees Indicating
People/Society	humans and/or their groups/institutions	<ul style="list-style-type: none"> - Flood Victims - Political Impacts - Protecting People - Social Impacts - Project Team (designers, engineers, etc.) - Project Economics (who pays for it) - Neighboring Communities - Government - Population Density - Social Demographics - Workers/Jobs 	21
Natural Environment	the ecosystem and/or components thereof	<ul style="list-style-type: none"> - Climate / Weather - Topography / Terrain - Ecosystem / Environment - Flood Intensity - Water Conditions 	12
Designed Artifact (retaining wall)	attributes of the wall and/or wall-centric activities	<ul style="list-style-type: none"> - Wall Aesthetics - Wall Cost - Wall Lifetime - Wall Materials - Wall Repair Ease - Wall Maintenance - Wall Construction Ease/Speed - Wall Base Elevation - Wall Dimensions - Wall Location - Wall Quality - Wall Strength - Wall Monitoring 	20
Aspects of Design Approaches	how design is done and/or aspects of the process of design	<ul style="list-style-type: none"> - Concretizing the Abstract (making it real) - Design Safety Margins (considered) - Worst-case Scenarios - Learning from Other's Mistakes - Unintended Consequences - Urgency (timeline) - Similar Incidents - Failure Issues 	21

* The codes comprising these categories are not mutually exclusive by participant (see codebook in Appendix D.2). Most participants indicated multiple ways in which their knowledge of Hurricane Katrina influenced their design task response.

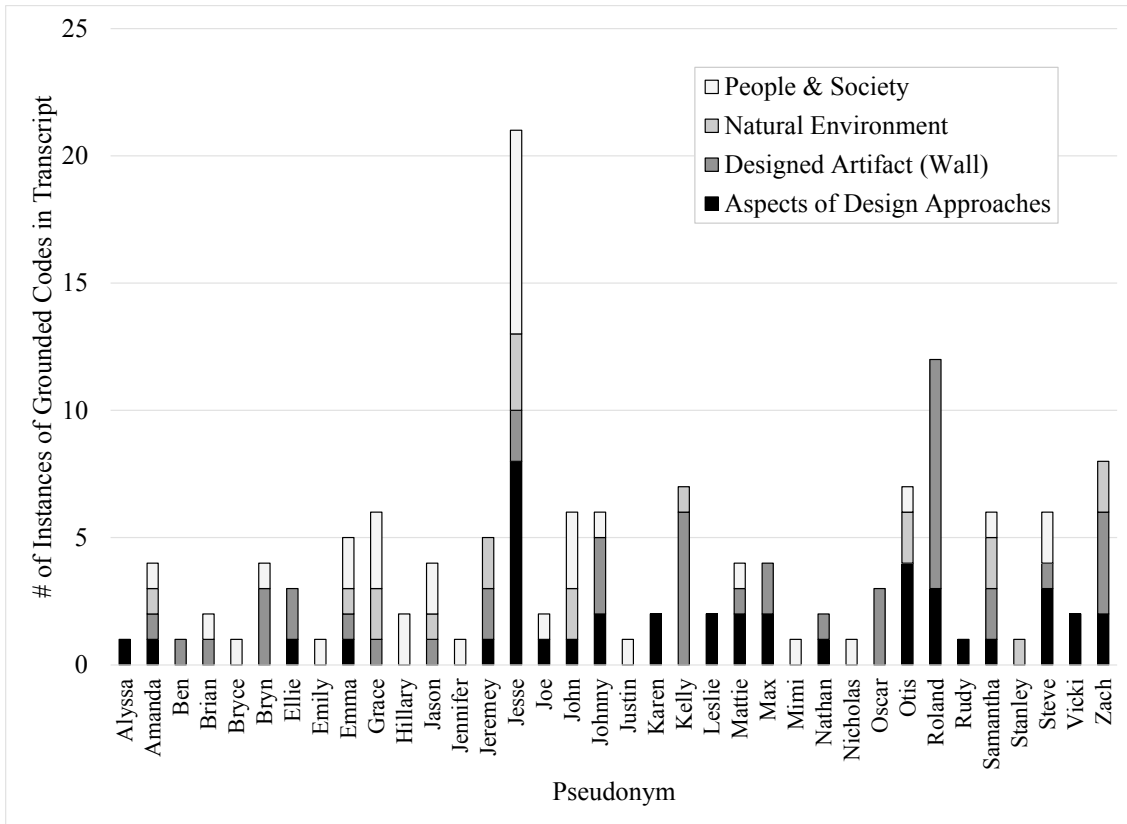


Figure 3. Variation in Grounded Code Occurrences by Participant

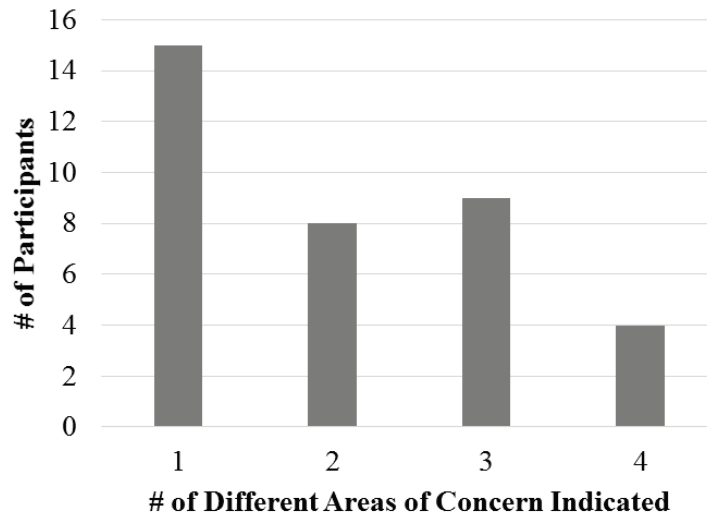


Figure 4. Breadth of Considerations in Aggregate

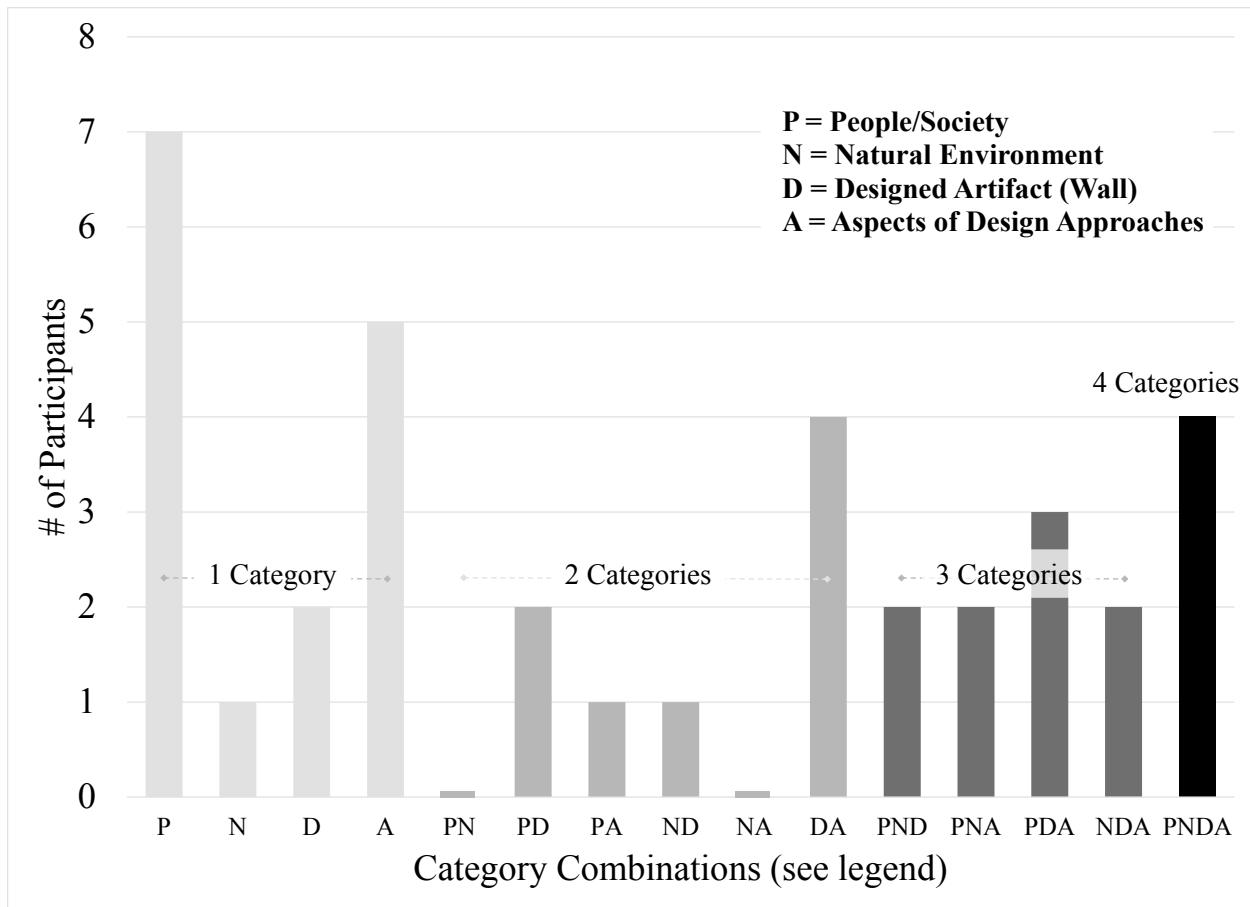


Figure 5. Breadth of Considerations Disaggregated by Category

3.3.2a. Illustrations of the “People/Society” Category

The “People/Society” category is comprised of responses indicating consideration of humans, groups of humans, and their institutions interacting with the design in any direction of influence, i.e., humans being affected by the design, as well as the design being influenced by humans. As was summarized in Table 6, this category includes mention of such things as flood victims, government, neighboring communities, political impacts, population density, project economics (e.g., who pays for it), project team (e.g., designers, engineers, etc.), protecting people, social demographics, social impacts, and workers/jobs. Quotations illustrating these ideas are presented below, beginning with consideration of people and their protection, followed by indications of potential economic impacts, then other indications of social/societal consideration, and concluding with notions at the intersection of society and the environment.

People and their Protection

The most prevalent theme that occurred in this category was consideration of people. This theme sometimes occurred in the form of general considerations of people, such as the following statement from Emily:

“Um, just made me think about how it would affect the people around it” —Emily (10)

Some students, such as Otis, spoke of people in the aggregate though indications of cities (i.e., large collections of people):¹²

“I thought what would the effect be on New Orleans...” —Otis (11)

However, many students were a little more specific, such as two who talked about evacuation, two who mentioned protecting humans, or Mattie, who was concerned about mortality:

“Well, I was thinking about Hurricane Katrina this time, and just that’s why I think I was a little focused on loss of human life” —Mattie (12)

A number of students also mentioned issues related to the housing and homes of people, such as Bryce, who said,

“I took into account the neighboring communities or housing.” —Bryce (13)

Project Economics (e.g., who pays)

The next most prevalent theme prompted by Katrina were thoughts of the economic impacts of the disaster. Some were fairly specific, such as Jesse, who reflected on the economic impact Katrina had on local tourism:

¹² One might argue that Otis could just as well be thinking of New Orleans as a collection of buildings / infrastructure rather than as a collection of people; however, either conception is anthropocentric in that buildings / infrastructure are human creations serving (and sometimes creating) human needs, and thus, People/Society is the appropriate category.

“the whole area is completely impacted because, you know, the tourism is going ... to go way down or it's down right now, so they're not getting that money.” —Jesse (14)

Other students talked about financial burden or responsibility, such as Mimi, who brought up Hurricane Katrina without explicit prompting in comparison with her approach to the design task from two years previously,

“I thought more about like who would pay for it this time, ...I guess I relate it to... Katrina...” —Mimi (15)

Other students mentioned economics more generally, such as Jason, who briefly indicated it along with several other considerations that his Katrina knowledge prompted:

“It's all about the social, the economic, the environmental impact.” —Jason (16)

This quote was therefore coded twice for the People/Society category (once each for “social” and “economic”), and once for the Natural Environment category, which is described in Section 3.3.2b below.

Other Social and Societal Issues

One theme that occurred in a few of the interviews was broad mention of social and societal issues, such as in Jason’s quote (16) above. Some students, however, such as John, went into a little more detail regarding the type of societal considerations they had in mind:

“Oh, and a good one is I thought about the societal impact of, you know, there was definitely the question of do we want to rebuild this town here in this little, you know, place with lower elevation with the surrounding bodies of water, is this even worth rebuilding.” —John (17)

Intersection of Society and the Environment

The last theme to discuss in this category is considerations at the intersection of society and the environment. Only a few instances of this occurred, such as Jesse, who recalled how the expansion of cities can (and has) affected the environment in ways that are detrimental to humans:

“...the disappearing wetlands that acted as like natural filters of this water—not filters, but natural levies... But with the expansion of New Orleans, those were all just covered with cement ... so there's no natural drainage left, so when the water just came in...” —Jesse (18)

3.3.2b. *Illustrations of the “Natural Environment” Category*

The “Natural Environment” category includes responses directed at the physical, natural environment and its interaction with the retaining wall. As was summarized in Table 6, this category contains indications that Katrina knowledge prompted consideration of the ecosystem and/or components thereof, such as climate/weather, flood intensity, topography/terrain, and water conditions. Quotes illustrating these ideas are presented below according to direction of influence—the natural environment affecting the design and potential impacts of the design on the environment—followed by consideration of flooding causes.

Natural Environment Affecting the Design

Many students noted aspects of the natural environment that would affect their designs of the retaining wall, with references to storms and water level being the most numerous. Jeremy described how weather conditions would inform wall design, even describing the wall in terms of storm intensity:

“Maybe I should say it can take a Class 3 storm and take a Class 5...” —Jeremy (19)

Other students talked about considering river water-level fluctuation, in storm conditions and otherwise, such as Stanley who said,

“First, Katrina came back, came to mind, so I was just thinking about the highs and the lows of the river and the normal.” —Stanley (20)

A few students spoke of considering the environmental context at a more macro level, such as elevation, nearby bodies of water, and Emma who was

“...thinking about the geography of the area.” —Emma (21)

Potential Impacts of the Design on the Natural Environment

Complementing the above examples concerning the environment affecting the wall design, some students considered the wall's potential impacts on the environment. These students were fewer in number, however, and their remarks were generally less specific, such as Jason in quote (16) who simply indicated "environmental impact". One exception to this brevity was Otis who thought about downstream effects of containing river flooding, wondering about delta areas like New Orleans:

"And then...negative effects elsewhere, I thought what would the effect be on New Orleans, since it's I think at the mouth of the Mississippi." —Otis (22)

Causes of Flooding

Another way in which Katrina prompted consideration of the environment was evident in students who stepped back to consider potential causes of river flooding. Jeremy asked aloud,

"Am I just trying to prevent the natural flooding that may be a lot of rain over the spring and the Mississippi floods?" —Jeremy (23)

Other students described how flooding can be anthropogenic, such as Jesse who, in quote (18) above recalled the significance of inadequate natural drainage. Amanda even explicitly suggested closer examination of the causes of flooding before constructing retaining walls:

"So that all goes to because we're harming the environment, and that's pretty much what matters. If we can fix that, then we can fix a lot of things." —Amanda (24)

3.3.2c. *Illustrations of the "Designed Artifact" Category*

The "Designed Artifact" category includes responses directed at the designed artifact: the retaining wall itself. As was summarized in Table 6, this category contains indications that Katrina knowledge prompted consideration of attributes of the wall and/or wall-centric activities. Examples of wall attributes include wall aesthetics, base elevation, cost (in the absence of a payer),

dimensions, lifetime, location, materials, quality, strength, and ease of repair. Examples of wall-centric activities include wall construction ease/speed, maintenance, and monitoring.

Wall Attributes

Most responses in the designed artifact category were indications of specific attributes of the wall, a common theme being the strength of the wall. Zach provides an example of this in response to being asked how Hurricane Katrina influenced his response:

“Probably that reaffirmed my thought that of anything that happens, strength is the most important.”
—Zach (25)

Another common theme in this category was the cost of the wall. Note that instances of this theme are restricted to general indications of the cost of the wall without reference to 1) a payer, because that is covered by the People/Society category, and 2) the application of cost as a design strategy (i.e., cost-benefit analysis), since that is covered in the Aspects of Design Approach category. Oscar and Johnny both very clearly indicated that Katrina knowledge added cost to their design tasks responses:

“...the budget questions were also there [in the design task response], too, because, you know, money was a restriction.”
—Oscar (26)

“And also for the cost, I also put cost restraint.”
—Johnny (27)

Interestingly, a few indications of cost issues were even made that minimize the importance of cost, such as Jason who said,

“I mean cost isn't always everything in a project.”
—Jason (28)

A somewhat less common theme was the physical dimensions of the wall (e.g., height, length, thickness, size). Jesse, for example, after describing some other ways it influence his thinking indicated the height of the wall was a consideration for him:

“but you also want it tall enough that they're not going to break if something comes in,”
—Jesse (29)

Another somewhat less common theme was the physical materials out of which the wall was made. Nathan clearly demonstrates this in the following quote:

“...so my understanding of that situation was that maybe it was the -- it was the materials that they used, they used in the levies, that weren't strong enough to withstand the force of the flood. So that's why one of the things I'm considering here is the material needed for building the retaining wall, yeah, so. . .”
—Nathan (30)

Wall-centric Activities

Some responses in the Designed Artifact category were directed at activities closely related to the wall, including maintenance and construction. For example, Kelly talked about the

“need to have a backup plan for how to keep it that way [strong], like even if it is what you want it to be, then you need to maintain it and need to check on it and need to be able to sustain it over time.”
—Kelly (31)

Similarly, Roland talked about

“...how easily will we be able to build these retaining walls...”
—Roland (32)

3.3.2d. Illustrations of the “Aspects of Design Approaches” Category

The “Aspects of Design Approaches” category is conceptually distinct from the previous categories of the designed artifact and its environmental and human social contexts. This category includes responses indicating how design is done or aspects of the process of design, and not attributes of the resulting design/artifact or artifact-centric activities, which are covered by the “Designed Artifact” code; in other words, it is process-focused rather than object-focused. As was summarized in Table 6, this category is comprised of such indications as concretizing the abstract (making the task real), design safety margins (considered), failure issues, learning from other’s mistakes, recognition/comparison of similar incidents, anticipating unintended consequences, urgency (timeline), and considering worst-case scenarios (a type of heuristic design approach).

Recognition of Parallels with the Design Task

Many students saw parallels between the Katrina event and the design task to which they were responding. Some even made it explicit how this guided their thinking, such as Max, who said,

“Um, it's like the exact same thing. Everything was from that. So everything that I wrote down was stuff that you think about after, you know, evaluating Katrina.” —Max (33)

Learning from Past Failure

One common theme that occurred in many of the interviews was the idea of learning from past failures, which is an important, if often overlooked, strategy for design. Consideration of the cause of failure was indicated by many students, such as Alyssa, who, in response to Q8 (i.e., did knowledge of Katrina affect design task responses) spoke of learning from failure causes in a general, non-context-specific way:

“Yes, it definitely did, because first, like say you have to figure out why it happened, and if you know the reason for it, you have to come up with reasons, you know, to solve it and what can make it better. So, yeah, it definitely did make me look at the situation a little bit wiser, I guess you would say.” —Alyssa (34)

Additionally, some students reflected on specific causes of the New Orleans levy failures as an aide to their design thinking, such as Steve, who said,

“I remember one of the reasons that the dikes failed in New Orleans is that the bank underneath got undercut or the foundation got undercut somehow, I forget exactly the details, but so taking that into account is a very important thing,” —Steve (35)

Other students talked about the effects or consequences of failure, such as Jesse, who among other considerations, was explicit about Katrina's impact on his design thinking:

“... and like these levies broke, and ... caused all this water to flow into a city, and so just the consequences of that... You know, that definitely had an impact on what I thought.” —Jesse (36)

In this theme, there were also some interesting exceptions to consideration of failure's causes and consequences as described above, such as Mattie, who spoke of designing for failure scenarios:

“...I didn't talk about a fail-safe system and a second wall in my earlier analysis, and I -- that was pretty much directly out of what happened in Hurricane Katrina, I think.” —Mattie (37)

Also, Rudy spoke about system failure, implying the culpability of the design engineer:

“Um, I guess basically the only thing it changed is I knew that I would not want to be the designer for the system that failed to that scale, to that degree, 'cause all the other things were things I would have considered.”
—Rudy (38)

Assessment of Risk

Another common theme was indications of risk assessment, such as Steve, who said,

“It's important to design things that are built to withstand much more than you think it's going to have to [withstand].”
—Steve (39)

and Samantha, who spoke of thinking about designing the wall with the magnitude of expected storms in mind:

“I guess maybe also on how big of a disaster the wall can withstand, like if ... there could be larger storms, like can it hold back the water from that, too?”
—Samantha (40)

Cost Tradeoffs

A somewhat less common theme that emerged in this category was the idea of making tradeoffs between cost and other design constraints. Most students in this theme reported considering cost-effectiveness, such as Roland, who actually wrote the following in his design task response:

“I recall during Hurricane Katrina, many of the levees broke due to the massive floods. In designing a retaining wall, one would obviously want to design it to withstand any potential loads, and it should be designed so that it will easily last a long time. At the same time, we shouldn't pour unnecessary funds into it. In designing this retaining wall, one would want to design something that is cost-effective and practical ... and at the same time will do its job sufficiently.”
—Roland (41)

An interesting addition to considerations of cost-effectiveness was Jesse, who, reflecting on why the government did not want to renovate the levies when they had the chance, talked about the costs of failure:

“But you also think about economics, because for the reason that they didn't do it was because it would have cost like, you know, \$5 billion, \$6 billion, whatever, to, you know, renovate the levies

exactly how they wanted to, so they didn't want to put that kind of money in because they couldn't give them a definite answer about when a category 5 hurricane would come. So they didn't put it out because they didn't want to spend \$6 billion now, but they've already spent over a hundred [billion dollars] [and will] spend hundreds [of billions] by the time this thing is all done... So the impact of not spending that \$6 billion is going to be like over a trillion dollars when it's all said and done, so just all those issues that really came -- that you have to think about when you're doing engineering problems...”

—Jesse (42)

3.4. DISCUSSION & INTERPRETATION

In this section I discuss and interpret the findings presented above. Paralleling the previous section, I start with a discussion of *if* (i.e., whether) Katrina knowledge affected design task responses, followed by *how* it did so (for those who provided such indications). In each subsection, I first look briefly through the conventional lens at the “face values” of the responses, before delving more deeply into the data through the lens of care ethics.¹³

3.4.1. DISCUSS/INTERPRET: DID KNOWLEDGE OF KATRINA AFFECT RESPONSES?

As shown in Table 5 (Section 3.3.1), which summarized *if* (i.e., whether) knowledge of Hurricane Katrina affected design task responses, a majority of the students (59%) reported that their knowledge of the disaster indeed affected their design task responses in some way; however, many (38%) also indicated that it did not (the responses of the remaining 3% of participants were

¹³ It may be worth noting here that for some readers, the idea of looking at the data through a lens as value-laden as care-ethics may seem uncomfortable and even problematic. Indeed, one might argue: should we not be attempting to remove the biases of any lens and examine the data uncolored and “as it is”? However, note that this assumption of seeing the data “as it is” ignores the fact that this data is not inanimate physical material examined for its physical descriptive qualities using an external measurement instrument, but is instead comprised of socially and contextually dependent human responses examined for the purpose of better understanding the complexities of human thinking, all while using human beings as the very instrument for data collection and analysis. The idea that research on human subjects conducted by human researchers could be performed without an interpretive lens is viewed by many with suspicion. Consciously or not, we all have lenses that make certain things more visible and other things less visible. As a physical analog, note that even the human eye itself has a lens through which all the light we perceive must pass. We cannot very well speak of removing that lens without impairing the very faculty of our sight. Furthermore, there are times when we benefit from placing physical lenses over our eyes for the purpose of altering and enhancing our perception, e.g., via microscopes to see the very small, or telescopes to see the very distant, or even glasses to correct for flaws in our “natural” vision that are caused by genetic and/or environmental factors. In this work, I make explicit effort not to forget that conventional “face values” are one lens that many people are accustomed to using and that care ethics provides another lens that I believe has great value for the different perspective it provides.

ambiguous with regard to whether or not Katrina knowledge influenced their design tasks). From the conventional “face value” perspective, we might look at this difference as an issue of learning transfer, i.e., the ability to extend knowledge or skills learned in one context to new or different contexts (see Bransford, Brown, & Cocking 2000, Chapter 3). Some students, such as Michael in quote (9), simply did not make the necessary mental connection between the design task to which they were responding and their knowledge of Katrina. Thus, what students may have learned elsewhere (often in informal learning environments) about the flooding caused by Hurricane Katrina, did not transfer to the design task in spite of the similarities between the two contexts (e.g., structures that retain water and flooding occurring in the middle of the United States). Further considerations / implications on the matter of learning transfer will be explored in Section 3.6.1.

From the perspective of Tronto’s framework for care ethics, these findings at this relatively coarse level of analysis (i.e., a binary if/whether Katrina knowledge influence design task responses) are both encouraging and potentially troubling. The fact that most students indicated that their knowledge of Hurricane Katrina, a major humanitarian disaster affecting hundreds of thousands of people in their own country, influenced their design task responses is encouraging because it suggests at least some level of care-ethical Attentiveness to others and their needs. On the other hand, the fact that Katrina knowledge did not influence so many students in spite of Hurricane Katrina's prevalence in the media at that time might seem at first alarming from the perspective of care-ethical Attentiveness: comparable, perhaps, to losing a friend in a car accident and then neglecting to mention it when talking with a child about the importance of wearing seatbelts. Note, however, that a number of possible reasons beyond issues of learning transfer exist that could excuse this apparent ethical lapse.

For example, it is important to remember that students were not provided any information about Hurricane Katrina by the research team and were not prompted to consider Katrina before completing the design task. Any knowledge they had and the primacy of Katrina in their minds depended solely on their previous experiences, habits, resources, and individual situations at that time. Responses to Q7 (what do you know about Katrina) indicated that the range of student familiarity with Katrina varied from very little to quite a bit. For example, John indicated he did not really know too much about it due to his isolation in a lab. Other students learned about the

disaster from reading the news or watching television. Some students knew others involved in post-Katrina clean-up, such as Oscar, who had friends go down to help with reconstruction, Jesse, who had a girlfriend go down to an impacted part of Mississippi to do relief work over spring break, and Hillary, who had a parent go down to help in an engineering capacity. Alyssa even had a close friend living in Louisiana, and Emma personally went down to help the disaster victims. Furthermore, variations in student access to the media would have a profound impact on the primacy of Katrina in their thinking, since those with both access and interest in TV, internet and other news sources would be acutely aware of the problem, but those without such proclivities and access would be much less aware.

3.4.2. DISCUSS/INTERPRET: WAYS IN WHICH KATRINA AFFECTED RESPONSES

As presented in Table 6 (Section 3.3.2), indications of *how* (i.e., ways in which) knowledge of Katrina affected responses to the written design activity were grouped into four “areas of concern”. These four categories were revealed in the initial analysis of data from a single institution (see Campbell et al. 2012) and when combined with data from the other participating institutions, has solidified with only minor changes in the naming of certain categories and thus providing some confidence in their legitimacy. Based on a first glance at Table 6, it may be tempting to highlight and begin drawing conclusions from the fact that Natural Environment was the least mentioned of the four categories. However, because this difference can be attributed to a number of possible causes, such as the likely prevalence of media coverage at that time on the human impacts of the disaster rather than the environmental impacts, or the relatively small size of the sample for quantitative comparisons, I feel it is best to defer speculations and related claims to future work.¹⁴

¹⁴ A similar word of caution is in order for Figure 4, which shows that, for some students, knowledge of Katrina prompted consideration of all four areas of concern, but for most students, only one category was mentioned in the interview. Here too, we must be careful not to over-interpret the findings, because there are several possible reasons why an interviewee could have omitted considerations. Ideally, we would hope that if the interviewee did not mention something it was because he or she really did not think of it; however, given the practical constraints of the setting in which the interviews were conducted and the fact that this was the last question of a lengthy protocol, it is also possible that interviewee and/or interviewer was tired, resulting in abbreviated or incomplete discussion.

From a conventional “face value” perspective, an interesting observation of Table 6 is that one of the four categories is of a conceptually distinct character from the others: Aspects of Design Approaches is a category characterized by reflection on self (metacognition around design) and/or broader reflection on engineering that involves a different level of abstraction than considerations of the designed artifact and its environmental and social contexts. Approaches to design could conceivably influence all other considerations, thus, in some sense subsuming the other categories. Indeed, many of the students with responses categorized in Aspects of Design Approaches also gave responses in the other categories such as Jesse’s quote (7), which indicated how Katrina knowledge helped him visualize (i.e., an aspect of design approaches) the consequences of a city flooding (i.e., a people/society consideration). With regard to relationships between the other categories, I observed overlap between (a) People/Society and Natural Environment, as shown in the quotes of Section 3.3.2a under the subheading of “Intersection of Society and the Environment”, (b) Natural Environment and Designed Artifact, as shown in Section 3.3.2b under the sub-heading of “Potential Impacts of the Design on the Natural Environment”, and (c) Designed Artifact and People/Society, as shown in Section 3.3.2c under the sub-heading of “Wall-centric Activities” through the implication of human actors necessary to perform maintenance and construction. Figure 6 attempts to capture graphically these ideas of overlapping areas of concern.

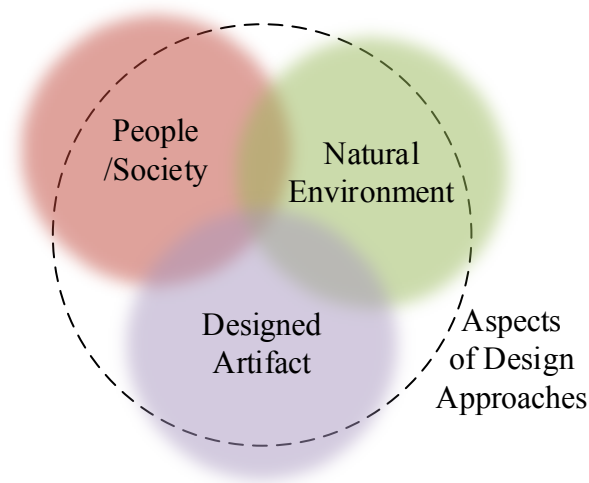


Figure 6. Relationships Between Areas of Concern

It is worth pointing out that the reason the above findings, when presented as “Areas of Concern,” might seem so reasonable without the addition of any value-laden lens such as care-ethics is because the implicit values they represent are mainstream. These values are thus less visible, indeed they need hardly be stated, because they are commonly endorsed by the academic and professional communities. However, with a little effort, we can uncover some of the values implicit in the categories above. For example, beneath the phrase "Areas of Concern" lies the implicit understanding that there are things with which we should be concerned. We might even share an unspoken understanding of the things engineers ought to concern themselves with in their designs. For example, perhaps people/society should be at the top of the list (even at the expense of the natural environment?) since ultimately it is people/society that engineers serve. Alternatively, for those interested in teaching and researching the topic of design, the Aspects of Design Approaches category might be the most highly ranked since it could conceivably influence all the other considerations.

From the perspective of care ethics, the categories of Table 6 are interesting because each seems to have a considerably different degree of conceptual link to care-ethical Attentiveness. The People/Society category has a very clear and direct link to care ethics and Attentiveness, as it is comprised primarily of care receiver(s) and their needs, i.e., the people impacted by wall failure and related societal costs. The Natural Environment category has a potentially direct link to care-ethical Attentiveness when considering the environment as an object of care and the needs of fauna, flora, and even the ecosystem. However, care for the environment proves somewhat hard to assess in this data set as explained below. The Designed Artifact category has arguably the weakest conceptual link to care-ethical Attentiveness, though given the narrow focus and brevity of the design task prompt, this is not surprising.¹⁵ However, when examined in context, a substantial number of indications of the Designed Artifact are clearly triggered by consideration of human and societal needs. Finally, the Aspects of Design Approaches category maintains an indirect conceptual link to care ethics and Attentiveness, as described below, and proves similar to the

¹⁵ Indeed, what is rather surprising is that Katrina knowledge triggered so many considerations other than those focused directly on the design artifact. From this we begin to see the value of the context that Hurricane Katrina provided: taking what would otherwise appear to be mundane and routine wall-centric design considerations and transforming them into salient concerns that are all the more compelling because they vividly remind the designer of the reasons behind performing such design work in the first place.

Designed Artifact category in terms of the existence of evidence for being motivated by human/societal needs. Thus, we find care-ethical Attentiveness reflected in all four categories of student responses to varying degrees.

Under the sub-headings that follow, I discuss in more detail the findings from the perspective of care-ethical Attentiveness. Recall that the findings are focused on the self-reported influence of student knowledge of Hurricane Katrina on the Midwest Floods design task. Thus, the discussion/interpretations presented here suggests care-ethical Attentiveness only with respect to the influence of Katrina knowledge on the design task and should not be over-interpreted or presumed to apply to other contexts.

Discuss/Interpret the “People/Society” Category

The People/Society category has arguably the closest link to care-ethical Attentiveness, as it is comprised primarily of human stakeholders and their needs: namely the people who would be impacted by the retaining wall, its failure and the related societal costs. In fact, when considered in the full context provided by the interviews, all passages in this category showed evidence of some degree of Attentiveness as conceptualized above (see Section 3.2.1b), and most instances indicated awareness of both others and their needs. For example, Bryce in quote (13) indicated that he took neighboring communities or housing into account, which shows awareness of not only the potential flood victims, but also their immediate physical safety needs and longer-term needs for shelter, as clarified by his response to the preceding interview question (Q7, knowledge of Hurricane Katrina):

“I just know that the flooding was massive and that it was more than anything they had ever expected and caused ... lots of damage and lots of people losing their homes and people losing their lives also.”
—Bryce (43)

For Jesse, attentiveness to the higher-level needs of a means of livelihood are apparent in quote (14), which talked about the “whole area” of New Orleans being impacted and the reduction in tourism causing local people not to get the money they needed to make a living. Another,

somewhat unusual higher-level need that came up was that of aesthetics or beauty as held by the community living near the retaining wall:

“I guess I did kind of think about that...I guess more on the appearance, just because that's our community, so there would be a couple of things.” —Samantha (44)

Based on the context provided by the rest of the interview, I can interpret Samantha to have meant that the wall appearance is important because aesthetics have an influence on a community, such as their sense of pride or self-respect. Therefore, Samantha's quote was coded for both “Designed Artifact,” since the appearance of the wall was her focus, as well as for “People/Society,” since consideration of “our community” was the explicit motivation for aesthetics consideration.

The context of the design task, being of a large-scale civil engineering nature, tends to preclude interpersonal “micro-ethical” levels of care considerations and predisposes it to societal “macro-ethical” levels of care. For Bryn, “society needs” illuminated by Katrina were even mentioned explicitly as having affected her design task response, however, from her response to the previous interview question (Q7, familiarity with Hurricane Katrina), we can see clearly the specific needs and social justice issues she had in mind:

“... lots of people lost their livelihood. I mean there was a lot of ... racial issues came up in the process. We got to see a very poor part of our country that sometimes people ... either choose not to look at or, you know, just turn their heads to. So I think that that was a big social implication and that these are predominantly black people, and so that was the racial aspect of it. And how our government handled things. I mean that's always politically a -- I mean it's always there when something like this happens, and some of the comments from some of the people. I remember watching something about the mayor making a comment about building the black city back up or something about it being a black city when you know there are a lot of white people there, too. So there's a lot of this friction. So a lot occurred during that and made us realize a lot that's wrong with -- I mean there's always wrong things in the country, but hopefully it doesn't take more natural disasters like that to make us aware of the needs of people in our own country.” —Bryn (45)

As powerful as the above quote was in illustrating care-ethical Attentiveness to others and their needs, not all interviews revealed such explicit thinking. Indeed, there were several cases that showed awareness of others without a corresponding explicit indication of need. For example, in quote (10) by Emily, Hurricane Katrina made her think about how the retaining wall “would affect the people around it”. It is unclear from this brief statement specifically what kinds of effects or needs she may have had in mind. Prior context in the interview from Q7 (what do you know about

Katrina) suggests it may have been issues related to politics, governmental response, and/or racism, but since even needs related to these issues were only implied, I can only be confident that Katrina directed her attention to the people in the vicinity of the retaining wall.

There were also several instances of need awareness without clear indications of the specific others who hold those needs. For example, in quote (12), Mattie's Katrina knowledge caused her to be if only "a little focused on loss of human life," which is very clearly a case of Attentiveness to the physical safety needs of people in general, although it only implies neighboring communities or potential flood victims. Similarly, Johnny clearly had several specific human needs in mind, including economic, health, and educational needs:

"... it seems like it was costing a lot of money to rebuild the cities, so how you factor that to spend a big chunk of money, a big percentage, into rebuilding the wall versus the hospital, the educational systems..."
—Johnny (46)

Note that while Johnny in the quote above did not explicitly mention any individuals, groups or entities, he implicitly indicated awareness of someone or something being financially responsible for repairs after wall failure. On its own, however, awareness of a financier would not indicate care-ethical Attentiveness as operationalized above because there is neither indication nor implication of a need held by the financier.

Discuss/Interpret the "Natural Environment" Category

Like the previous category, the Natural Environment category could also be viewed as being comprised of the needs of a care receiver, namely the animals, plants, and ecosystem. However, the relatively low number of occurrences in this category,¹⁶ combined with the brief ways in which they were discussed often makes it difficult to infer Natural Environment as an object of care in the minds of many of the participants. In spite of this, the interviews of a couple of individuals contained evidence of awareness of both non-human others and their needs. Specifically, Amanda in quote (24) talked about the cause of the flooding being "because we're harming the

¹⁶ As Table 6 reveals, roughly half the number participants mentioned this category compared to those who mentioned the other three categories.

environment,” which clearly demonstrates awareness of the environment, and through use of the word “harming” shows awareness of its need for safety, health, or well-being. Similarly, when talking about how the construction of the levies in the first place actually made the impact of Hurricane Katrina worse, Grace observed that reason was

“... because it interfered with natural processes...”

—Grace (47)

This effectively identified the ecosystem as an “other” with a need to perform its natural processes, a conception reiterated and clarified later in the interview when she talks about her knowledge of Hurricane Katrina:

“they didn't really know much about like the swamp area or like the -- a lot of the natural processes that were happening, and so they built things just to enable more people to live there, so they like put up these levies and a bunch of, yeah, like shipping channels that brought in sea water that like destroyed marshes and things like that that people didn't really take the environment into consideration. And so it, yeah, it created this bowl-like shape for the City of New Orleans, in between the Mississippi and Lake Pontchartrain...”

—Grace (48)

The quote above illustrates an interesting issue, pointing out the conflict that so often exists between human needs or wants and the ability of the natural environment to sustainably support them.

There were also a handful of instances demonstrating awareness of non-human others with implied needs. For example, Jason in quote (16) indicated “environmental impact,” where we can infer that a need exists for the environment to be non-impacted. There were not, however, any instances of the converse, where need was explicitly indicated but the non-human other was implied. Most of the instances in the Natural Environment category, however, suggested a more neutral or perhaps utilitarian view of the natural environment. For example, Stanley indicated “thinking about the highs and the lows of the river” in quote (20). Given the absence of even an implied need, this passage thus does not provide evidence of Attentiveness. Similarly, in talking about monitoring the wall’s condition, Kelly mentioned physical attributes of the river water without identifying or implying any needs of non-human others:

“...you definitely have to ... keep watch to make sure that pressure doesn't change, that the atmosphere in the water doesn't get colder or hotter...”

—Kelly (49)

Discuss/Interpret the “Designed Artifact” Category

Given the narrow focus and brevity of the design task prompt, one might intuitively expect the Designed Artifact category to have the weakest link to care-ethical Attentiveness. If we were to follow the form of the discussion in the previous two subsections, we might attempt to talk about care of and attentiveness to the Designed Artifact, i.e., the retaining wall. However, it would be odd to consider the wall as an “other” and even more difficult to conceive of the wall as having needs that are compelling in the same way they are for living things. Indeed, few people would be comfortable talking in such a manner using an anthropomorphism of the designed artifact. Of course, the reason for an engineer to design a retaining wall (or any designed artifact) in the first place is ostensibly to serve the needs of others, usually some human end-user. With this in mind, even here in the Designed Artifact category, we find clear examples of care-ethical Attentiveness (i.e., awareness of others and their needs) through consideration of attributes of the retaining wall. In fact, most of the participants coded in this category indicated at least one such association showing awareness of others and/or needs.

Some of these participants indicated both other and need awareness, such as Samantha’s mention of the wall’s appearance in quote (44) as motivated by community needs for aesthetics or beauty. At a lower level of human need, Emma spoke of a relationship between the base elevation of the wall and the safety needs of the people during evacuation:

“...I heard about...some of the concerns from like designing for Katrina, problems with New Orleans, how the levies there were designed, or like how it was -- were designed from -- I don't remember where it was from, but it was so low to -- so close to the sea level. That was a problem when people were trying to drive past it to evacuate...”
—Emma (50)

In the Designed Artifact category, most instances of Attentiveness were indications of need awareness where the “other” was an implied other. For example, Kelly, in responding to Q8 (did Katrina knowledge affect your response) implied helping or protecting people (i.e., potential flood victims) when talking about the wall’s strength requirements:

“A little bit, because, you know, something -- yeah, the levy broke. Yeah, if something's gonna -- if you're going to build something that's supposed to help, it needs to be resistant, it needs to be strong...”
—Kelly (51)

Also, for a number of these participants, cost of the wall was a consideration, and in spite of not indicating who bears the financial burden (which would then have been categorized under People/Society), still showed awareness of financial need. For example, in replying to Q6 (educational experiences that helped with the design task), Ellie recalled Hurricane Katrina, indicating the need to minimize cost and its relationship to wall strength:

“I mean I think that we -- it's not educational, but I think the whole thing with the hurricane... I know like a big factor for them was like cost and trying to minimize cost... And, you know, in trying to minimize cost they ended up getting something that was weaker than it should be...”
—Ellie (52)

Awareness of others (with implied needs) was observed for a few participants, such as Ben, for whom Katrina knowledge prompted consideration of the elevation of the area:

“...the hurricane came, and the way the -- the way the levies were built, they weren't either built properly or they failed, and since New Orleans was under sea level, and a lot of the areas around there are under sea level, it just kind of filled up...I was really concerned with the elevation of the area that we're talking about in the Midwest, because you have to plan for a retaining wall differently if it was way above sea level than if it was below sea level.”
—Ben (53)

Finally, at least in the context of the influence of Katrina knowledge on the design task, some responses in this category do not show evidence of Attentiveness, since only consideration of the Designed Artifact is indicated without mention of others or needs. For example, Nathan, in quote (30) drew on his technical understanding of a known problem with the levies in New Orleans and indicated wall materials as a resulting design consideration. While his response to the previous interview question (Q7, what do you know about Hurricane Katrina) showed awareness of the human impacts of the disaster, including mortality, displacement, property damage, and the inadequacy of the governments' response, when prompted by Q8 (did what you know about Katrina influence your design task), not only was his response a qualified yes (“Yeah, to some extent, yes”) but his scope immediately changed from human impacts to technical causes of failure as indicated in quote (30), with no evidence of any direct connection between the two. Thus, within the scope of this analysis I did not find evidence of care-ethical Attentiveness in his self-report of the influence of Katrina knowledge on his design task response.

Discuss/Interpret the “Aspects of Design Approaches” Category

One might expect the Aspects of Design Approaches category to have at best an indirect link to care ethics and Attentiveness; however, similar to the Designed Artifact category, we find many instances of awareness of others and their needs through consideration of aspects of design approaches. It is clear in many interviews that behind the higher-level reflection on design thinking lies a desire to do a better job of designing the retaining wall out of concern for the people the wall is intended to protect. Like the Designed Artifact category, most of the participants in this category indicated at least one such association showing awareness of others and/or needs.

In this category, most instances of Attentiveness were indications of both others and needs. For example, Mattie, in quote (37), indicated that she did not consider a fail-safe system and using a second wall in her 1st-year response to the design task, but did so in year 3 due to the influence of Katrina. In the context of her earlier remark in quote (12) from the same short turn regarding her focus on loss of human life, this is clearly an example of care-ethical Attentiveness triggered by her knowledge of Katrina. Similarly, we can see awareness of others and their needs in Max’s response by first considering his response to the previous interview question Q7 (what do you know about Katrina), which evinces awareness of potential flood victims and their needs:

“...I know there was a very, very large hurricane that nobody really anticipate -- well, that the majority of people didn't really anticipate coming, and it hit New Orleans hard, and people were not evacuated...”
—Max (54)

This in turn prompted reflection on and learning from the past mistakes of others in response to Q8 (did what you know about Katrina influence your design task):

“...you obviously learn from that that if you're going to build a wall you want it to be worthy, so instead of looking at building the cheapest wall, you want to build a good wall.”
—Max (55)

While this quote also illustrates consideration of the Designed Artifact (wall quality and wall cost, and, in the context of the previous quote, links it with awareness of human needs), it is the notion of learning from the Katrina disaster that I wish to highlight here, because this was a common theme (as indicated in Section 3.3.2d) and is suggestive of the potential for the case method of

teaching in engineering education to improve care-ethical Attentiveness. More on this and other implications will follow in Section 3.6.1.

Some instances of Attentiveness in this category were indications of needs where the “other” was an implied other. For example, Leslie indicated two themes discussed in Section 3.3.2d, namely “recognition of parallels with the design task” and “assessment of risk.” Her response to Q7 (what do you know about Katrina) provided directly related context, as she first talked about having read technical reports about the levies in New Orleans that gave warnings and discussed known problems with their design. She then went on to talk about how the levy breaking caused most of the damage, indicating the need for elevated housing foundations in anticipation of hurricane induced flooding:

“Cause I think the levy, the breaking of the levy is what caused most of the disaster and most of the damage, and so that's why it's such a big focus. Because it's definitely a hurricane-prone region, and so they know a lot of that, like a lot -- I mean you just look at how the houses are built and they're built on queues (phonetic), is that how you say it? They're raised up, elevated, because it's below sea level...”
—Leslie (56)

Thus, this example shows indication of need awareness with only implied indications of who has the need.

Awareness of others (with implied needs) was also observed in this category for one participant, Otis, who demonstrated broader design thinking by considering unanticipated consequences of the design:

“And then, you know, negative effects elsewhere I thought what would the effect be on New Orleans...”
—Otis (57)

Finally, some responses in this category do not show evidence of Attentiveness since only consideration of Aspects of Design Approaches are indicated without mention of others or needs. For example, Karen talked about how seeing the effects of Hurricane Katrina made the design task more real and also mentioned learning from the mistakes of others:

“Just the, you know, being able to see the effects, like obviously the hurricane, helps to, you know, solidify like this is a problem and that I can see on the news how these engineers were approaching

it, and you see the effects of what would happen if you don't approach it correctly. Because obviously, you know, there was a problem with their retaining wall.”

—Karen (58)

While this example does not cite needs or those who have them and thus cannot be viewed as care-ethical Attentiveness, the importance of learning from the mistakes of other engineers/designers has implications for other phases/elements of care ethics, namely that of Responsiveness. Care-ethical Responsiveness involves the care-giver, in this case the engineer/designer, being responsive to the needs of others and aware of whether and how their needs can be met. An important aspect of Responsiveness from Tronto’s perspective is the way it highlights differences in power and vulnerability, and these are certainly present in the relationship between engineer/designer and the public or end-user. Furthermore, Tronto points out that “adequate responsiveness requires attentiveness”, which illustrates Integrity—the interconnectedness of the moral elements of care—as described in Section 2.2.1.

3.5. LIMITATIONS OF THE STUDY

Before presenting implications of this study, a few words on its limitations are in order. Note that I make no claims of statistical significance for my findings and that the work should be viewed as exploratory rather than explanatory. The data used in this study are comprised of student self-reports of the influence of their Katrina-knowledge on the design task. While I have no reason to doubt the sincerity of student responses and have seen no evidence of students attempting to placate the research team, I acknowledge the possibility of social desirability bias given the context and nature of the questions. However, the fact that a significant minority of students (28 per Table 5) claimed their knowledge of Hurricane Katrina did not influence their design task responses seems to disconfirm the likelihood of widespread social desirability bias in this data set. For that matter, neither have I found evidence of interviewers leading or fishing for responses with regard to the topic analyzed in this data set.

Another possible source of bias present in the data is a result of the branched protocol used, which attempted to limit the length of the interviews by including the Katrina-related questions (Q7&8) only if the students did not compare their Year 1 and Year 3 design task responses (Q3&4).

At one school, the research team asked fewer students to compare their year 1 and year 3 responses (and thus more students to answer Q7&8), and at another school, the research team only loosely applied the branching scheme, instead asking most students the Katrina-related questions even if they had already answered Q3&4. As shown on the Institution row of Table 4, both of these practices resulted in relatively larger numbers of student responses from these two schools being analyzed in this study. Thus, the perspectives of students from Large Public University and Urban Private University may be somewhat over-represented in this work compared to the other two schools. While institutional comparisons are beyond the scope of this work, I note here that the number of students who spontaneously indicated that their Katrina knowledge influenced their design task responses was notably higher for the other two schools (i.e., Suburban Private University and Technical Public Institution).

Regarding the possible effect of differential priming of some students compared to others due to the branched protocol, it occurred to us that the students who indicated their Katrina knowledge did not influence their design task responses (see Table 5 in Section 3.3.1) might have been less primed than those for whom it did if they were of the subset of student not asked to compare their Year 1 and Year 3 design task responses (i.e., Q3&4). This hypothesis, however, proved unlikely, as 11 students were asked both Q3&4 and Q7&8 and yet still gave negative responses compared to 9 students who were asked both sets of questions and gave positive responses. Thus, in this data there appears to be no relationship between level of priming and negative response.

With regard to the design of this study, I remind the reader that the mid-west floods design task exercise and the post-task, semi-structured interviews used in this study were conducted in an educational research lab setting rather than in a classroom, and the study was not intervention based, thus, participants received no prior prompting or background materials in preparation for the design task. Furthermore, I acknowledge that the analysis was performed post-hoc: data was not initially collected with any particular theoretical or interpretive framework (e.g., Tronto's framework for care ethics) in mind.

Given that a considerable fraction of the study population was comprised of international students (16 of 73), another possible problem with the data can be attributed to the wording of the

design task question, which would likely have been more meaningful to native speakers of English. Having lived in Asia and the Middle-East for 7 years, and having been married to a non-native speaker of English for more than a decade, I am particularly sensitive to such issues. The design task read: “Over the summer the Midwest experienced massive flooding of the Mississippi River. What factors would you take into account in designing a retaining wall system for the Mississippi?” I suspect that some students would have (1) been unsure where “the Midwest” was located and (2) interpreted “the Mississippi” to be the State of Mississippi rather than the river. While such interpretations were probably not common, they could explain some of the “No” code of Section 3.3.1.

Finally, with an eye towards implications, it is worth pointing out that Hurricane Katrina, and its aftermath in New Orleans and surrounding areas of the Gulf Coast, had been covered heavily in the news for the eight to nine months immediately preceding the student interviews that provided the data for this chapter.¹⁷ Nearly a decade later, however, the prominence of Hurricane Katrina in the minds of people today is likely to be much lower than in the first few years immediately following the disaster. Furthermore, the salience of Hurricane Katrina is lower still for current undergraduate engineering students, because, unlike the students in this study, who were aspiring engineering at the time of the disaster, most of today’s students would have been too young to identify with engineers when the disaster struck and could not then appreciate the role of engineering in both causing and addressing the problems. Similarly, for future engineering students, Hurricane Katrina will be well before their time and thus of lower salience. However, there have been other humanitarian disasters since Katrina, such as the 2008 and 2010 earthquakes in China and Haiti, respectively, and there are sure to be others in the future, for which we (as engineers, governments, NGO’s, and the public) can only hope to be more attentive, responsive and better prepared. Hurricane Katrina thus represents one example of a humanitarian disaster from which engineers could learn to improve their Attentiveness and thus expand the breadth of their design thinking in order to better recognize and, where appropriate, address the needs of others.

¹⁷ Hurricane Katrina struck land in late August of 2005, and the design task exercises and post-task interviews used in this research were conducted in April and May of 2006.

3.6. IMPLICATIONS & FUTURE WORK

In this section, I present a selection of implications for teaching and learning design that are of interest to educators and then conclude with ideas for educational researchers about possible directions for future work. Some of these implications stem directly from the findings, and some are associated at a higher level with the intersection of analysis, method, and conceptual framework as developed in the work.

3.6.1. IMPLICATIONS FOR TEACHING AND LEARNING ENGINEERING DESIGN

Several implications for teaching and learning design emerge from this work. In the subsections below, I begin with a focus on the findings that relate to the transfer of learning in one context to performance in another context. Next I show how the work makes care-ethical attentiveness more concrete by extending the work into the area of educational assessment. Finally, I conclude the section with a suggestion for using the study's emergent high-level categories as a framework to aid in teaching and learning about the complexities of design.

3.6.1a. Facilitating the Transfer of Learning to Other Contexts

As suggested in the first paragraph of Section 3.4.1, the findings have implications for learning transfer: the ability to extend knowledge or skills learned in one context to new or different contexts (Bransford, Brown, & Cocking, 2000). Anderson et al. (1996) indicate that “the amount of transfer depends on where attention is directed during learning or at transfer.” From the perspective of care-ethical Attentiveness, this is quite significant because I am in essence suggesting that engineers must learn to be more conscious of where their attention is directed when they do their work (more on this idea to follow in Section 3.7) and that there are ethical reasons for attending to others and their needs.

Some students explicitly pointed out their knowledge of Hurricane Katrina as having helped them with the design task. Thus, a common theme that emerged from the interviews was the notion

of learning important design considerations from real-world events like the Katrina disaster (see Sections 3.3.2d and 3.4.2). My findings thus suggest that simply invoking (i.e., prompting) pre-existing knowledge of well-known humanitarian issues, like those caused by Hurricane Katrina, could help engineers think beyond the narrow confines of purely technical considerations during design. We, as educators, should be doing more to leverage these kinds of opportunities to encourage broader, more care-ethically attentive design thinking.

Explicit Prompting May Be Needed

However, the substantial number of students in this study for whom transfer apparently did not occur, either because of insufficient knowledge of Katrina (e.g., low levels of initial learning) or because they failed to see relationships between the design task and the disaster (e.g., unsuccessful far transfer) confirms that such an approach to teaching problem scoping in engineering design would be more widely effective if invocation of the humanitarian issue were supplemented by helping students connect it to the design task at hand. In other words, explicit prompting will be needed for some people. As a case in point, Michael—who indicated in quote (9) that, while he now sees the link, his Katrina knowledge did not influence his response because he did not think of it the same way—was asked an off-protocol follow-up question: “You just mentioned that it’s interesting that you didn’t think of Hurricane Katrina, but ... now that you have given it a little bit of thought ... is there any way that it would affect how you approached this problem?” Michael’s response confirms the potential of simply highlighting the context of Hurricane Katrina in order to prompt broader considerations and awareness of human needs:

“I might have been able to like – like I put a bullet for, say, like social impact, but I didn’t like put anything under it, but if I had thought about Hurricane Katrina, I probably could think of certain reactions people would have to stuff or maybe other issues dealing with maybe the other solutions, things might have came up, or maybe like the cost of rebuilding, because I didn’t really think about if the area had been flooded, then it would probably be really hard to like build a retaining wall of any sort of massive – any sort of massive structure because the infrastructure around it wouldn’t be there. I didn’t really consider that. I just was thinking about building a retaining wall like anywhere...”

—Michael (59)

Anderson et al. (1996) confirm the need for explicit prompting in educational settings, adding that “[t]raining on the cues that signal the relevance of an available skill [or knowledge] should probably receive more emphasis in instruction than it now typically receives.” With this in mind,

one way to encourage broader thinking and care-ethical Attentiveness might be to employ the design task prompt used in this study¹⁸ as a classroom or self-study exercise appended with the following prompt: “When writing your responses, consider what you know about the aftermath of Hurricane Katrina on the people of New Orleans and/or on the surrounding ecosystem.”

More generally, I suggest that a broader design context that improves Attentiveness by incorporating consideration of people and the environment (like that inherently provided by the invocation of Hurricane Katrina or other humanitarian disasters) can be leveraged in both formal and informal educational settings to improve the broad thinking skills necessary to address issues such as sustainability, ethics, and even social justice (see Riley, 2008). These issues particularly require concern for living (and sometimes non-living) things, and I join others (e.g., Bowen 2009, Chapter 6) in the assertion that awareness of such issues is important to cultivate in engineers who might otherwise be overly technology focused.

Given the simplicity of adding such a prompting to consider Hurricane Katrina (or other prominent and relevant humanitarian problem of the day), the findings of this study suggest that even small changes in the kinds of design problems and problem-framings educators employ can effect broader thinking and care-ethical Attentiveness during design. Perhaps this could be considered a minimalistic way of accomplishing some of the objectives of more comprehensive teaching approaches like project-based learning (PBL) in design (see Dym et al., 2005), the case method of teaching,¹⁹ and model eliciting activities (MEAs).²⁰ I encourage educators to try

¹⁸ Repeated here for convenience from Section 3.2, Table 3, Question 1:

“Over the summer the Midwest experienced massive flooding of the Mississippi River. What factors would you take into account in designing a retaining wall system for the Mississippi?”

¹⁹ The case method is a form of inductive (rather than deductive) teaching that is commonly used in the fields of business, medicine, and law to help students learn to deal with the complexity of the real world. In engineering education, the case method typically finds application in teaching engineering ethics (e.g., see www.onlineethics.org), and may also be used in teaching design in conjunction with ethics (see Gorman, Mehalik, & Werhane 2000).

²⁰ Model eliciting activities (MEAs) are a relatively new educational approach adopted by engineering educators and researchers from the math education literature. Essentially, MEAs are case study problems that simulate authentic, real-world situations and are solved by small teams of students over one or more class periods (Hamilton et al. 2008). The core feature of an MEA is an iterative process of expressing, testing, and revising models to solve the problem. MEAs may also be extended to include ethical considerations (see Shuman et al. 2009).

incorporating these and other techniques that facilitate consideration of the social and environmental consequences of engineering design in their classrooms.

3.6.1b. Making Care-ethical Attentiveness More Concrete

One outcome of this work was to operationalize an element of care-ethics (i.e., Attentiveness) in terms of demonstrated awareness of others and/or their needs. For example, as described in Section 3.2.1b, I coded interview transcripts for passages that cited specific needs, whether the entities in need were clearly identified or just implied. This shows just one of several possible ways to make the abstract notion of care-ethical attentiveness more concrete and in so doing, make it more approachable and useful to engineering students. These notions of needs and others could be used to create exercises, checklists, or rubrics for formative and/or summative assessment of student work. For example, students could be asked to brainstorm a list of needs their designs aim to meet, identify who has those needs, and then consider what new needs their designs may inadvertently create (and for whom).²¹ Students themselves could also use needs/others checklists or rubrics formatively to assess their own work and/or that of their peer. Similarly, course instructors could use such rubrics summatively as a principled means of evaluating breadth of design considerations while grading project deliverables or other student work.

3.6.1c. A Framework for Highlighting Design Inter-relationships

With the goal of utilizing knowledge of a humanitarian disaster to teach design in a way that is more care-ethically Attentive to the needs of others, I am essentially suggesting a need to move students from thinking about the designed artifact in isolation, to a view that is more holistic. Recall the findings summarized in Figure 4 (Section 3.3.2), which indicated that Katrina knowledge prompted considerations in only one category for many people, and the relationships between Areas of Concern depicted in Figure 6 (Section 3.4.2). Figure 7 (below) illustrates a possible learning goal for those students who tend to focus disproportionately on the Designed

²¹ Of course, one might argue that good design practice begins by identifying needs to address, rather than doing this later, teaching and learning engineering design often involves design activities in which such considerations are implicit, pre-determined, or sometimes even absent.

Artifact: namely that they move their thinking from left to right in the figure by 1) giving more weight to considerations of People/Society and the Natural Environment, 2) becoming more metacognitive of their design approaches and their implications, and 3) exploring possible intersections between each of these categories.

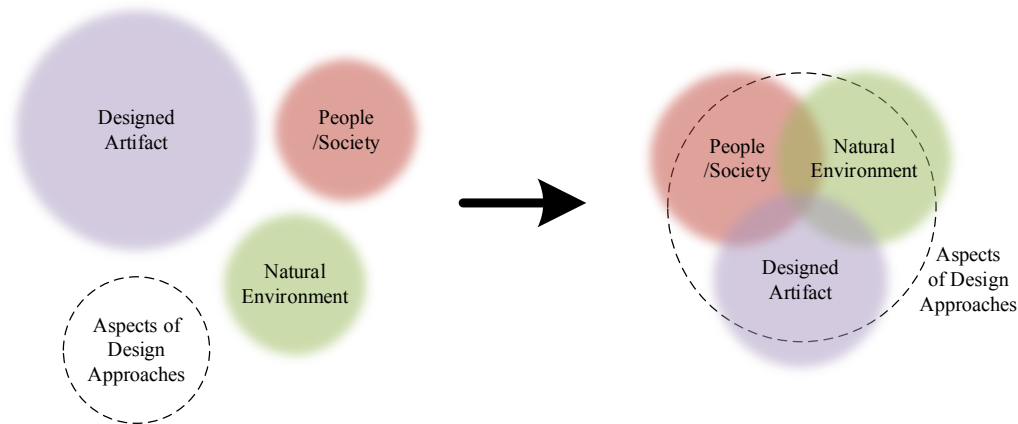


Figure 7. Moving from Disproportional Focus on the Designed Artifact to a More Balanced View of Design Inter-relationships

Like the needs/others conceptualization of care-ethical attentiveness described in the previous sub-section, one way to implement these Areas of Concern in the classroom is to create assessment rubrics based on the broad categories of People/Society, Natural Environment, and Designed Artifact (as described in Section 3.3.2). Students could use these formatively to assess their own work or that of their peers, and/or instructors could use them summatively to evaluate breadth of design considerations when grading student work.

3.6.2. FUTURE WORK

In this subsection, I present several ideas for future work, including suggestions to explore reasons for variation in student responses, and reasons why knowledge of the disaster did or did not influence student thinking. I then present hypotheses and some brief preliminary findings for quantitative follow-up work.

One interesting finding with implications for educational researchers is the variation in both the number individual considerations (see Figure 3 in Section 3.3.2) and the number of areas of concern elicited by the implicit Hurricane Katrina framing (see Figure 4), with some students indicating multiple considerations across multiple categories and some indicating but a few. Reasons for this variation should be explored as they would inform the design of course materials and teaching/learning strategies that encourage broader considerations in the problem scoping phase of design.

Another opportunity for future work stems from Michael's statements in quotation (9), which indicated reasons why his knowledge of Hurricane Katrina did not influence his thinking on the design task. This question of why was not part of the interview protocol and did not come up in many of the transcripts (and thus further analysis was not pursued), but for the purpose of understanding student thinking to inform course and curriculum design, educators would clearly benefit from learning why Katrina knowledge did or did not influence so many responses. The interested reader is referred to Campbell et al. (2012, p. 11-13) for a brief summary of preliminary findings from a single institution (i.e., Large Public University) on why knowledge of Katrina did or did not influence design tasks.

While the primary purpose of this chapter was to describe and explore the data qualitatively and through the lens of care ethics, I have also observed some quantitative trends that are worthy of mention and perhaps future exploration. Given the relatively small sample sizes and the absence of a theoretical grounding to suggest directions of causality, the following empirical relationships should not be viewed as methodological findings, however, I report them here to motivate and suggest possible hypotheses for future work.

One angle I explored was the possibility of relationships between the categories of Table 6 describing how (i.e., the ways in which) Katrina knowledge influenced the design task. While the sample size in this analysis was low ($n = 36$) and subject to various types of sampling error (discussed in Section 3.5), I did find a modest, positive, and statistically significant correlation between the number of instances of the People/Society category and the Natural Environment category. In other words, those students who indicated more codes in the People/Society category

also tended to indicate more codes in the Natural Environment category. From the perspective of care ethics, this suggests that, for those students for whom Katrina knowledge elicited greater Attentive to the needs of People/Society, it also elicited greater Attentiveness to the needs the Natural Environment (and/or vice-versa). This, in turn, might suggest that those students with greater proclivities for Attentiveness tend to be Attentive to life in general (e.g., humans, plants, animals, etc.) as well as to that which is necessary to sustain it (e.g., weather, nutrient cycles, etc.). Understanding and encouraging such Attentiveness in engineers could lead to new designs, new industrial processes, and even new approaches to engineering, which may be necessary to improve the environmental sustainability and social justice of the engineering enterprise.

Interestingly, I also found a similarly modest positive and statistically significant correlation between the number of instances of the Aspects of Design Approaches category and both the People/Society and Natural Environment categories. In other words, those students who indicated more Aspects of Design Approaches also tended to indicate more considerations in both the People/Society and Natural Environment categories. While no direction of causality can really be inferred here, future work might be guided by the hypothesis that broader and more care-ethically Attentive design considerations would emerge from students with approaches to design that are more metacognitive, such as those manifested in the Aspect of Design Approaches category.

Other angles I explored briefly included the possibilities of correlations based on demographic differences, such as sex, institution and major. For example, with regard to a possible relationship between sex and if (i.e., whether) Katrina knowledge influenced design task responses (see Table 5), I found no statistically significant difference between female ($n = 27$) and male ($n = 44$) responses for this data set. Of course, further work in this area would benefit from controlled experiments and larger samples sizes.

3.7. CONCLUSIONS

In this chapter, I explored the self-reported influences of informally obtained knowledge of Hurricane Katrina on a conceptually related design scoping task that was completed by third-year engineering students in the spring of 2006. The exploration began with an inductive, descriptive

coding of if/whether knowledge of the disaster influenced student thinking, and if so, how. The analysis was then followed by an explicitly interpretive layer that looked at the ways in which Katrina knowledge influenced design thinking through a lens of care-ethical attentiveness. Attentiveness was operationalized via explicit and implicit considerations of others and their needs as mentioned in the interviews in relation to the influences of Hurricane Katrina knowledge. The findings were then discussed in terms of both layers of the analysis. Limitations of the study were then described, followed by a discussion of the study's implications.

One finding from the analysis was that most (nearly three fifths) of the students in the sample reported that their knowledge of the disaster indeed affected their design task responses in some way; however, many (over a third) indicated that it did not (see Table 5). These findings have implications for learning transfer (see Section 3.6.1a) that could help engineers think beyond technical design considerations. For example, they suggest that the skills of broad thinking and care-ethical attentiveness can be improved simply by invoking pre-existing knowledge of humanitarian/social justice issues in the classroom; however, while learning transfer between contexts may occur naturally/spontaneously for many students, explicit prompting to connect the contexts will likely be needed for some. Furthermore, as common themes in the interviews suggest, perhaps even small changes to the way we teach/learn design can affect the skills of broad thinking and care-ethical attentiveness.

In terms of care ethics, the findings at this coarse level of analysis might also suggest relationships between student thinking and Attentiveness to others and their needs. The fact that Hurricane Katrina knowledge influenced most students' thinking is encouraging; however, that it failed to influence so many students (despite its prominence in the media and its relevance to the design task) should not necessarily be viewed as morally problematic given the circumstances of the study, which provided no instruction or prompting to consider the hurricane prior to completing the design task.

Another finding from the analysis indicated that knowledge of the disaster, when it was a factor, caused students to consider issues related to four categories or areas of concern: People/Society, the Natural Environment, the Designed Artifact, and Aspects of Design

Approaches (see Table 6). Furthermore, this knowledge caused most students (nearly three fifths of those for whom it was a factor) to consider issues related to multiple areas of concern; however, considerations were limited to only one area of concern for many students (i.e., over two fifths of those for whom Katrina knowledge was a factor—see Figure 4). With regard to care ethics in the ways in which Katrina knowledge influenced design thinking, Attentiveness was reflected to varying degrees in the quotes comprising all four categories of student responses; however, the significance of the selected quotations and interpretations do not summarize very meaningfully in a concluding paragraph because the meaning is in the details; thus, I refer the reader to Section 3.4.2 (e.g., see Discuss/Interpret the “People/Society” Category).

At this more detailed level of analysis, these findings and methods used suggest several implications for teaching and learning design, such as further supporting the learning transfer implication described above. The work also makes care-ethical attentiveness more concrete, extending its applicability into the area of educational assessment, such as for self- and/or peer-assessment. The study’s emergent high-level categories can also be used as a framework to aid in teaching and learning about the complexities of design. Avenues for future work using both qualitative and quantitative methods are also implicated.

I now conclude this chapter with some higher-level ideas and suggestions for how engineers can and should use care ethics to guide them in some of their design considerations:

Moving from Problem Scoping to Final Designs

The design task used in this project focused exclusively on the problem scoping phase of design, which primarily occurs early in the design process. It is valuable for designers to recognize the importance of contextual concerns about (i.e., Attentiveness to) people and the environment in the early phases of design, but this is just a first step. A question for engineering educators and practicing engineers alike is how to support following through with broader, more Attentive design thinking into the later stages of design. Curricula for both undergraduate engineering education and continuing education might need to incorporate additional knowledge and methods necessary for students to understand and address these contextual concerns by including such topics as

history, philosophy, or sociology as they relate to modern engineering challenges. The literature and practices of several extent design approaches, if used appropriately, can also aid in improving care-ethical Attentiveness, namely user-centered design (see Mao, et al., 2005), participatory design, sustainable design, and value sensitive design (see Friedman, Kahn, & Borning, 2006). Similarly, the literature and practices of stakeholder analysis (see Appendix B.1 for a brief introduction) could be helpful. In fact, much has been written on the relationship between care ethics and stakeholder analysis (Engster, 2011 provides a brief overview), and those familiar with the latter will likely recognize the parallels between Attentiveness and the stakeholder identification phase of stakeholder analysis. However, Attentiveness (and care ethics) goes beyond stakeholder identification by helping us keep in mind that: 1) there are potentially many others (human and non-human) who may be effected by engineering work, 2) those others have needs of varying levels of primacy, and 3) we have an ethical responsibility to try to understand those needs not from our own perspective as engineers, but from the perspective of those who are affected by our work. For example, we need to pay extra attention power differentials and give special treatment to the more vulnerable populations, such as children, the poor, the elderly, and even the natural environment.

Care Ethics as a Guide for Design Considerations

When thinking about the purpose of engineering, as traditionally conceived, one might argue that the category of Designed Artifact is in fact the natural purview of the engineer's attention²² and that the reason behind "caring about" technical details in the first place is an implicit care for society and/or the end user. While this may indeed be a primary motivation for some people, less altruistic motivations are surely paramount for others, such as the desire to make money (e.g., for themselves and/or their families), or the desire to solve problems (i.e., the desire for a sense of gratification derived from overcoming challenges). In terms of public perception, engineers have historically done a poor job of demonstrating care for people/society as evidenced by a national survey that found engineers were perceived to be significantly less sensitive to societal concerns

²² Note that the idea of care-ethical Attentiveness is not invoked here, because practically speaking, it makes little sense to talk about the "needs" of the design artifact.

and less caring about the community than scientists (NAE 2008). Part of engineering's poor public image can be attributed to the way most engineers work at a distance (both temporal and physical) from the beneficiaries of their designs (Bowen 2009) and this tends to preclude the formation of personal relationships, such as those that care-givers like doctors and nurses enjoy with their patients. It is interesting to note that the idea of aiding people in need through pro-bono work has not historically been a part of the prevailing engineering culture (Baum 1985) until recently with the advent of such organizations as Engineers without Borders (see, e.g., Schneider, Lucena, & Leydens 2008). Given the frequent existence of a gap between designer and end-user in engineering, there is all the more reason for engineers to be cognizant of that distance, and both willing and able to mitigate its effects.

I suggest that engineers must (pardoning the expression) take care not to allow the tacit nature of their motivations for attending to the Designed Artifact (and even Aspects of Design Approaches) to unconsciously influence their decisions about what they do as well as how and why they do it. Clearly a conscious, deliberate and critical process of decision making is preferable to one that is unconscious and blind to its own biases. In fact, the argument could be made that part of the engineer's ethical and professional responsibility is to care about and be attentive to those technical aspects of the design (both the designed artifact and processes of designing it) in service to the public welfare, as is frequently reflected in the various codes of ethics articulated by the various engineering disciplines. It is thus important for engineers to articulate this, make it explicit, and remind themselves of the true meaning and purpose of their work so that they maintain a sense of priority and perspective that keeps other interests, such as personal financial gain, corporate profit, or even vain pride from tacitly becoming the overruling driver of their work. Perhaps care ethics can be employed to provide a kind of meta-criterion for guidance in identifying and prioritizing criteria for engineering design.

Chapter 4. Engineers’ Responsibilities for Global Electronic Waste: Exploring Engineering Student Writing Through a Care Ethics Lens

This chapter continues the empirical exploration, examining the second of three humanitarian/social justice contexts: “back-yard” electronic waste recycling. It is comprised primarily of a journal paper manuscript¹ that looks at the ways in which students wrote about engineers’ responsibilities for the human health and environmental impacts of “backyard” electronic waste (e-waste) recycling that presently occurs in many industrializing countries, such as India and China. The final publication is available at Springer via <http://dx.doi.org/10.1007/s11948-016-9781-2>. This chapter builds on the previous chapters by adopting and developing the second of Tronto’s elements of care ethics, Responsibility, in an engineering context. It addresses the second part of the second research question (RQ2/RQ2-B) as well as a portion of the third research question (RQ3).

¹ Campbell, R. C. & Wilson, D. (2016). Engineers’ Responsibilities for Global Electronic Waste: Exploring Engineering Student Writing Through a Care Ethics Lens. *Science and Engineering Ethics*. <http://dx.doi.org/10.1007/s11948-016-9781-2>

4.1. INTRODUCTION

In Chapter 2, I described Tronto's framework as a whole (see also the summaries of it in Campbell, Yasuhara, & Wilson 2012 and 2015), but in this chapter, I focus on a single element, Responsibility, because it is an important concept and one that is not well understood in a care-ethical sense, especially in an engineering context. However, before describing care-ethical responsibility in more detail, I should first say something about ethical responsibility more broadly.

4.1.1. ETHICAL RESPONSIBILITY IN GENERAL

Much has been written on the subject of responsibility in a moral or ethical sense² (e.g., see Eshleman 2014; Fischer & Ravizza 1998; Frankfurt 1969), though it is well beyond the scope of this work to review all such literature. In the field of applied ethics for the disciplines of science and engineering, a search of all issues of Springer's journal of *Science and Engineering Ethics* (1,375 articles from 1995 to 2015) shows that variants of the words oblige and responsible (e.g., obligation, responsibility, responsibilities, irresponsible, etc.) occur in the titles of 128 articles. Six of these are from a recent special issue from a conference on moral responsibility in science and engineering (see Doorn & van de Poel 2012). Several of the articles in this special issue call for "a more empirically informed perspective on responsibility [that includes] taking an insider perspective and see[ing] what responsibility engineers take upon themselves, rather than focusing on holding responsible" (Doorn & van de Poel 2012). Another article from this special issue (Roeser 2012) calls for a reform of engineering curricula to include "courses that enhance the emotional and imaginative capacities of future engineers." In the present chapter, I contribute to answering these calls by examining students' positions on the responsibilities of engineers for the problem of e-waste recycling and by suggesting a topic, materials, and approaches to incorporating care ethics in engineering to enhance emotional and imaginative capacities.

² I use the terms moral and ethical interchangeably in this work.

4.1.2. CARE-ETHICAL RESPONSIBILITY

In Tronto's view of care ethics, Responsibility is a "central moral category" (1993, p. 131). When a need is identified, one must decide if one feels responsible for it and if so, how to respond. Care-ethical responsibility differs from other, more traditional notions of responsibility in five major ways.

First, it is not universal, but dependent on context: the best ethical response is a function of the situation and actors involved. Care-ethical responsibility considers both what should be done and what those involved are capable of doing. As an example regarding the latter, it is all well and good to say a parent is responsible for the health of their child, but if that parent is jobless, homeless, and without health insurance for reasons beyond their control, their ability to meet the healthcare needs of their child (let alone themselves) is severely impaired. Can the same level of responsibility be expected of them as by a well-to-do parent? Similarly, one might wish to claim universally that engineers are responsible for ensuring the things they design are safe to use; however, if the specified materials or components prove unavailable and alternatives are used during manufacturing or construction, how much influence is the design engineer capable of and how responsible should he or she realistically feel if the designed artifact fails?

Another difference between care-ethical and traditional notions of responsibility lies in the dimension of time: care-ethical responsibility tends to be future-oriented rather than looking to the past and is thus concerned with getting things done (meeting needs) rather than placing blame. In the previous example of the design engineer, rather than examining fault or liability, care-ethical responsibility would help us focus on the nature and scope of the actions the design engineer could/should take, such as anticipating material/component compromises by suggesting suitable alternatives, adding warnings to the design specifications regarding substitutions, and/or being involved in manufacturing or construction in some way that enables oversight of the materials used.

Adopting a care-ethical perspective also helps spotlight stakeholders who might otherwise be missed. A conventional ethical perspective might focus on causal responsibility, looking across the lifecycle from the design engineers and the companies for whom they work, to the consumers

and eventual disposers of a designed artifact or system. These are stakeholders who actively influence a given situation. In addition to these stakeholders, care-ethical responsibility reminds us to consider stakeholders who are affected by the situation and to even prioritize the needs of disadvantaged (e.g., vulnerable, powerless, or underprivileged) stakeholders. Disadvantaged stakeholders might include innocent people or the ecosystem when they suffer from pollution generated by the creation or disposal of a designed artifact or system. These stakeholders are not causally responsible, but the nature or severity of the impact they experience should strongly influence decision making, and this is more likely to happen if the ethical theory employed does not implicitly background them. Affected stakeholders could also have a role to play in addressing or preventing problems.

Another important aspect of care-ethical responsibility is related to the notion of responsibility ascription, i.e., deciding who is responsible. Care-ethical responsibility involves internal (personal and/or collective) volition rather than external compulsion. It is up to the individual (or group) to decide if they will assume responsibility for something, rather than having others externally impose that responsibility on them (e.g., by law, contract, or social pressure). It is thus a more aspirational approach to responsibility than that found in many ethical theories. As Tronto (1993, pp. 131-133) explains, Responsibility differs from obligation: whereas obligation typically arises out of formal agreements or promises made, responsibility is more contextual, flexible, ambiguous, and not necessarily associated with our prior actions (e.g., we might assume responsibility for helping someone simply because they have a compelling need that no one else is addressing). Whereas obligation means we have to do something as imposed by an external driver, responsibility means that we should do something regardless of any external compulsion.

Finally, in her more recent work, Tronto (2013, Chapter 2) made the point that individual responsibility is not enough: we have collective responsibilities that must be discussed and agreed upon collaboratively. This is especially pertinent in an engineering context to address such complex problems as those associated with “backyard” e-waste recycling. Tronto (2013, p. 63) suggests that a participatory, democratic approach to responsibility is needed to address the main pitfalls of care ethics, pitfalls known as paternalism, which involves some people assuming too much responsibility or authority, and parochialism, which involves setting the moral boundaries

too narrowly and only taking care of our own concerns. One might even view the present work as a first step towards a participatory, democratic approach to addressing the problem of e-waste in which engineering education researchers build on the views of engineering students (the next generation of practicing engineers) and initiate discussion in academic discourse. The next step would involve bringing the discussion into other venues to include the perspectives of additional stakeholders, such as practicing engineers and “backyard” e-waste recyclers.

With these differences between traditional notions of responsibility and care-ethical responsibility in mind, this study analyzes how students view the issue of e-waste in the context of this alternative view of responsibility provided by Tronto's conceptual framework.

4.2. METHODS

This section describes the methods used to collect and explore the data, beginning with the research question guiding the work. I then describe the source and selection of data,³ and then conclude with a description of my approach to coding and analyzing the data.

4.2.1. RESEARCH QUESTION

This chapter continues to address the dissertation’s second research question (RQ2), which read: In terms of care ethics, how do students in traditional engineering programs respond to problems of humanitarian or social justice nature? Specifically, the following sub-question (RQ2-B) guided this work: *How do students exhibit Responsibility (“taking care of”) in the context of “backyard” e-waste recycling?* Answers to this question might tell us whether or not students associate engineers with responsibility for this issue and the nature and scope of that responsibility. At the end of this chapter, I also explore some of its associated implications (RQ3), e.g., on teaching and learning engineering, further educational research, and engineering ethics including suggestions for educational policy and the practice of engineering.

³ Portions of the Data Source and Data Selection sub-sections were adapted from Campbell, Yasuhara, & Wilson (2012), which reported on a pilot study using a slightly different data set, and Wilson et al. (2013), which used the same data set but for a different type of analysis.

4.2.2. DATA SOURCE

This work explores samples of student writing on the topic of electronic waste recycling in industrializing countries. These samples were written in 2011 by undergraduate students at a large public research institution⁴ in the western United States. Students from a variety of engineering majors in a large, entry-level electrical engineering course were provided with an article on the health and environmental impacts of waste electronics in China and India. They were also given three questions pertaining to the article and asked to write a short (one to two page) essay as guided by the provided questions (see below). The assignment was optional and students were incentivized with extra credit to be applied to their course grades. The students had one week to complete the assignment.

The article the students read was entitled “A review of the environmental fate and effects of hazardous substances released from electrical and electronics equipment during recycling: Examples from China and India” (Sepúlveda et al. 2010). Students were directed to specific portions of this 14 page scholarly article to read in detail, namely: (a) the introduction (half a page), which provided brief context and background of the e-waste problem; (b) the paper’s only figure, which depicted the ecological cycle and the fate of pollutants generated by e-waste recycling; and (c) the fourth section (one and a half pages), which described environmental and health perspectives in China and India related to e-waste recycling activities. The following are the questions to which the students were asked to respond in their essays:

1. *What part of Waste Electronics Recycling in Figure 1 concerns you most? Why?*
2. *From the part of Waste Electronics Recycling process you chose in Question 1, what is the impact on humans? On ecosystems? (address air, water, or food quality as needed/desired).*
3. *What do you think modern engineers producing these electronic technologies should do as an "ethical" response to the waste electronics recycling dilemma? Comment specifically on how far in scope engineers should go to limit this impact.*

⁴ This school is classified as a doctorate-granting Research University RU/VH (very high research activity) according to the Carnegie Basic Classification (2010).

In terms of Tronto's framework, reading the journal article and answering the first two essay questions encouraged care-ethical attentiveness to a problem that should inspire some level of caring. In this context, the third question (and the phrase "*ethical*" response in particular) then encouraged responses compatible with care-ethical responsibility.⁵ Thus, the third essay question was the focus of my analysis. Note that the students received no instruction in this course on the topic of ethics in general or on care ethics specifically. My analysis thus provides a view of care-ethical responsibility that undergraduates might bring into the engineering classroom without prior study of or instruction in care ethics.

4.2.3. DATA SELECTION

All students in the class were invited to complete the essay for extra credit, and (also optionally) to release their work for this research. Students were fully informed (verbally and in writing) that their grades would not be impacted by their decisions on consent; furthermore, details regarding who provided consent and who did not were withheld from the instructor. Out of the 180 students enrolled in the course, 101 completed the extra credit assignment. After removing ineligible essays (e.g., those that were missing consent forms or their authors explicitly chose not to participate in the study), 84 essays were available for analysis.

The students' demographics were also collected as part of an associated but distinct study (see Allendoerfer et al. 2012) that was administered concurrently with the written extra credit assignment described above. The majority of the available participants were male, U.S. citizens of age 18 to 22, majoring in electrical or mechanical engineering, in the third (junior) year of their program, and of white/Caucasian ethnicity. However, I wanted to explore a demographically diverse sample of the available data that would be more likely to exhibit a broader range of perspectives and responses. Therefore, an intentional sample was selected that oversampled for women and non-citizens. Additionally, the criteria of major, ethnicity, and age were used to

⁵ As observed by an anonymous reviewer of this manuscript, use of the word "ethical" in the prompt makes the question less open-ended and less probing of student senses of responsibility than if the word had been omitted. I acknowledge this point. I also take this opportunity to invite the reader to consider whether the phrase "ethical response" might serve as lay-language for the notion of care-ethical responsibility.

achieve approximately proportional representations of each of these demographics from the available essays, thereby maximizing diversity to the extent possible across the available dimensions. The initial sample size was 17 essays, and 13 more were added after completing a portion of the analysis, bringing the total up 30. The purpose of the second sample was to improve coverage of demographics, increase confidence in data saturation and thereby minimize the risk of misrepresenting the data. The total sample contained writing from 10 women and 20 men including 19 US citizens, 4 permanent residents, and 7 foreign nationals. Self-reported ethnicities in the sample included 12 white/Caucasian, 10 Asian/Asian-American, 3 under-represented minorities (including Hispanic/Latino/Mexican-American and black/African-American), and 5 with multiple ethnicities. Their majors were as follows: 12 in electrical engineering, 9 in mechanical engineering, 3 in industrial engineering, 2 in computer science/engineering, and 1 each in bioengineering, civil/environmental engineering, materials science/engineering, and mathematics. Age ranges covered in the sample included 18 to 20 years (11 students), 21 to 24 years (16 students), and 25 to 40 years (3 students).

4.2.4. ANALYSIS APPROACH

In this work, I provide a qualitative view of what engineering students bring to the table in terms of care-ethical responsibility for the e-waste recycling problem. To achieve this, I performed two levels of analysis: the first was descriptive and provided a foundation upon which to build the second, more interpretive layer. Figure 8 outlines the approach, which I explain in more detail below. For both layers of analysis, I sought to cover the diversity of responses rather than report quantity or prevalence of response types (though these are also reported incidentally). The unit of analysis was the individual essay, using the entire essay written by each student. Analysis involved first reading the essay and demarking responses to each of the three essay questions wherever they happened to occur.⁶ Coding was based on units of meaning found in the text, thus codes were applied to passages of variable length including phrases, sentences, and/or paragraphs where appropriate. Coding was performed using ATLAS.ti qualitative data analysis software. Essays

⁶ Most, but not all students followed the structure suggested by the numbered essay questions, and some included introductions and/or conclusions that addressed multiple essay questions.

were anonymized and referenced using participant code numbers during the coding process. Pseudonyms were later chosen and applied during the write-up. Note that, while essays were initially selected based on student demographics (i.e., the intentional sample described above), the reading and coding of student writing was performed without knowledge of these demographics.⁷ All quotations included in this chapter were selected after coding, based on the following criteria:

- clarity of illustrating the code/category/idea
- coverage of a variety of different participants based on their survey demographics
- coverage of diversity (or breadth) of responses with respect to care-ethical responsibility

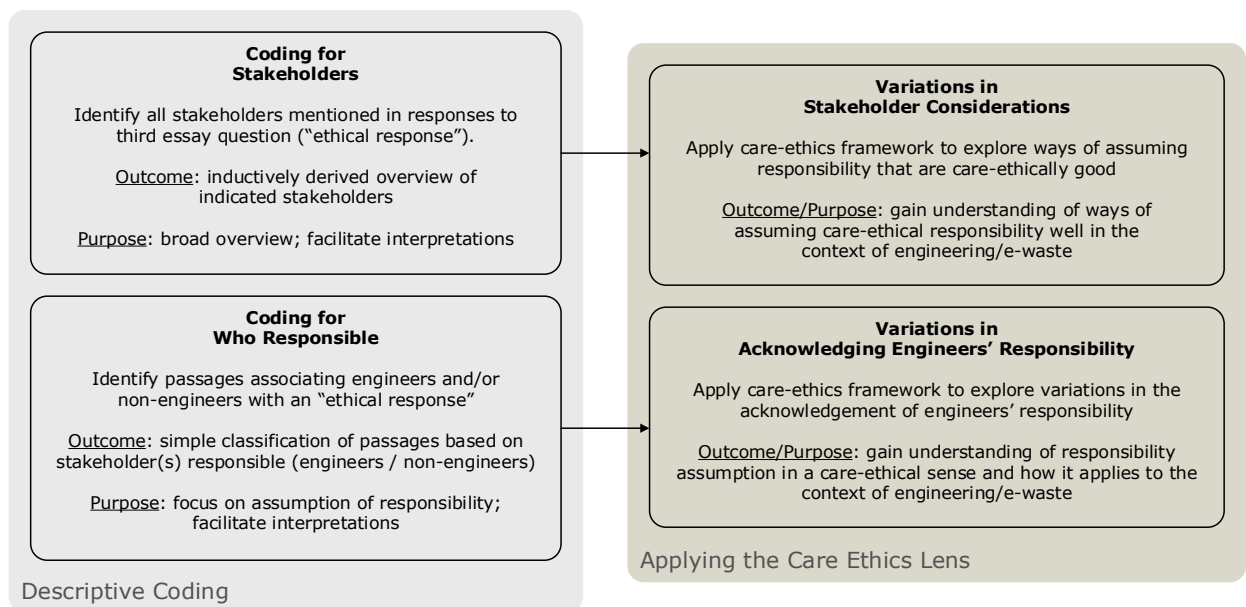


Figure 8. Coding Approach used for Analysis

⁷ However, in a few cases, clues about certain demographics were found within the essay either directly, such as through statements indicating a student's home country, or indirectly, through writing styles indicative of English as a second language. Nevertheless, a conscious effort was made by the coder to bracket this knowledge so that it did not influence the coding process, especially during the more interpretive phase of the analysis, in case patterns related to participant demographics should emerge (see future work in Section 4.5.3b).

4.2.4a. Descriptive Coding

The descriptive coding, summarized on the left half of Figure 8, involved operationalizing care-ethical responsibility in two ways. One way provided a broad overview of all stakeholders that students mentioned in response to the third essay question, and the other provided more focus by examining who students associated with responsibility for the e-waste recycling problem. Each of these are explained in more detail below.

Coding for Stakeholders:

This phase of the analysis involved reading through all responses to the third essay question (regarding ethical responses to the e-waste problem) and inductively coding the different stakeholders mentioned in each. Stakeholders were defined broadly as individuals, groups, institutions, or entities (including the natural environment) that are likely to affect or be affected by e-waste recycling/disposal. While the multiplicity and variety (i.e., breadth) of indicated stakeholders was the desired outcome, all direct instances of each stakeholder were coded to avoid missing any (pronouns were only coded if they clearly implied a stakeholder not previously stated). I expected this operationalization to provide insights into how well responsibility was being assumed inasmuch as the greater the number and/or variety of indicated stakeholders, the more likely that suggested or planned actions would positively impact the e-waste problem.

Coding for Who is Responsible:

This coding pass focused on responses to the third essay question with an eye for who was associated with responsibility. Rather than coding inductively, here I looked for indications of engineers and/or non-engineers as being either positively, negatively, or ambiguously associated with responsibility. These codes are summarized in Table 7 below and were not mutually exclusive at the essay level, thus multiple applications of these codes across multiple passages were possible in any given essay. In this analysis, the distinction between participant uses of the words “can” or “could” versus the word “should” was not emphasized. While these words carry considerably different weight in any context of responsibility, with the imperative “should” holding a much stronger position than the more optional “can/could,” idiomatic manners of writing and variations

in language fluency made such distinctions difficult to uphold. Given the question, “What do you think modern engineers ... should do as an "ethical" response...?” some students chose to respond with multiple suggestions for what engineers might do, listing possibilities with “can” or “could” rather than (or sometimes in addition to) identifying primary recommended actions. Rather than assuming (perhaps erroneously) that students made conscious and deliberate word choices in this regard, our coding captured indications of both the normative “should,” which occurred in the strong majority of coded passages, along with indications of the possibilistic “can/could,” for which there were relatively few instances.

Table 7: Passage-level Codes for Who is Responsible

Code	Description
Engineers responsible	Passages in which engineers are positively associated with responsibility for the e-waste problem.
Others (non-engineers) responsible	Passages in which others besides (possibly in addition to) engineers are positively associated with responsibility for the e-waste problem.
Unclear with respect to engineers’ responsibility	Passages that are unclear in their identification of engineers and/or their association with responsibility for the e-waste problem.
Unclear with respect to others’ responsibility	Passages that are unclear in their association of others (non-engineers) with responsibility for the e-waste problem.
Engineers <u>not</u> responsible	Passages in which engineers are negatively associated with responsibility for the e-waste problem.
Others (non-engineers) <u>not</u> responsible	Passages in which others besides engineers are negatively associated with responsibility for the e-waste problem.

Reconciling a participant’s position on the responsibility of engineers for the e-waste recycling problem occurred in the next phase of the analysis as described in the next sub-section. Note that, while the participants in this study were students and not practicing engineers, they were all majoring in engineering and thus likely aspiring to be engineers (even the math major, who had a second major in electrical engineering). Their statements about the responsibilities of engineers are therefore likely to reflect thinking about their own personal and professional values,⁸ rather than being statements that ascribe responsibilities to people other than themselves. I expected this

⁸ One student even articulated this explicitly with the statement “As a future engineer, I think that we should...”

operationalization to give insight into student conceptions of responsibility assumption⁹ and also to have implications on awareness of both the engineer's power for action and limitations or constraints on that power.

4.2.4b. Applying the Care Ethics Lens

In the second level of analysis, summarized on the right half of Figure 8, I built on the descriptive coding results, applying the care ethics framework introduced in Section 2.2.1. This involved examining the variations in both stakeholders indicated and acknowledging engineers' responsibility, which facilitated a preliminary, conceptual exploration of care-ethical responsibility within the context of engineering and e-waste recycling/disposal.

Variations in Stakeholder Considerations:

This phase of the analysis involved further operationalizing care-ethical responsibility via stakeholder considerations. Specifically, I examined (a) the multiplicity and variety of indicated stakeholders (i.e., the more and the more diverse, the better) and (b) considerations of disadvantaged stakeholders (i.e., those who are vulnerable, powerless, or underprivileged), such as children or innocent people. I examined the data in this way to measure or assess the quality of care-ethical responsibility present in the essays.

Variations in Acknowledging Engineers' Responsibility:

In this phase of the analysis, I built on the results of the "Who is Responsible" coding to arrive at a mutually exclusive categorization capturing each essay's position on the responsibility of engineers for the e-waste problem. This involved first making logical inferences based on the

⁹ Use of the phrase "responsibility assumption" in this work is intended to be used interchangeably with the phrase "assumption of responsibility." While the more common phrases of "responsibility acceptance" or "responsibility ascription" could also have been used, these were not chosen because the associated connotations of external assignment and blame are not consistent with the adopted care-ethics framework, which employs a more internal and voluntary notion of responsibility as described in Section 4.1.1 above.

“Who is Responsible” coding,¹⁰ and then re-reading student responses to the third essay question (and any related text necessary to understand context, pronouns, etc.) this time with an eye for discourse rather than content. Here I sought to capture the manner in which responsibility was expressed, as manifest by indications of limitations on engineers’ responsibility and/or the sharing of responsibility with others. This was an iterative process that ultimately led to the categories of essays shown in Table 8 below. These categories were mutually exclusive at the essay level.

Table 8: Essay-level Categories for Acknowledging Engineers’ Responsibility

Category	Description
Engineers’ responsibility acknowledged, unqualified	Essays in which engineers’ responsibility was simply acknowledged without qualification (e.g., without connotations of deflection, reservation, limitation, or sharing).
Engineers’ responsibility acknowledged and also shared with others	Essays in which engineers’ responsibility was acknowledged but also shared with others with no further qualifications (i.e., without connotations of deflection, reservation, or limitation).
Engineers’ responsibility acknowledged, shared, but limited	Essays in which engineers’ responsibility was acknowledged and shared with others, but the scope was explicitly limited or constrained in some way (e.g., <u>with</u> connotations of deflection, diffusion, or reservation, or was secondary to or contingent on the actions of others).
Ambiguous with respect to engineers’ responsibility	Essays that were ambiguous with respect to the responsibilities of engineers for the e-waste problem (e.g., because they neglected to mention engineers).

4.3. PREPARATORY FINDINGS (DESCRIPTIVE CODING)

In this section, I present the coding results, as well as brief discussions and observations that do not rely on the care-ethical framework presented in the introduction. The purpose of this phase of the analysis was to provide a descriptive, “close to the data” portrayal of student responses upon which the care-ethical findings of next section could build.

¹⁰ For example, the second and third categories of Table 8 applied to essays in which both engineers and others were associated with responsibility (i.e., contained at least one instance of “Engineers responsible” and “Others responsible” from Section 4.2.4a).

4.3.1. STAKEHOLDERS (DESCRIPTIVE CODING RESULTS)

Students indicated a variety of stakeholders in their responses to the third essay question. In this section, I summarize all stakeholders mentioned, regardless of their association with responsibility for the e-waste recycling problem (Section 4.3.2 looks at those the students associated with responsibility). Recall that stakeholders were broadly defined as individuals, groups, institutions, or entities, including the natural environment, who are likely to affect or be affected by e-waste recycling. These stakeholders are summarized below under the following broad categories: Technical/Economic, Citizenry, Government/NGO, and Natural Environment. A more detailed listing of all stakeholders indicated appears in Appendix E (see Table 15).

The Technical/Economic category included specific groups, such as engineers, electronics companies, manufacturers, and consumers of electronics, as well as companies and/or individuals involved in the recycling of e-waste. Some of these stakeholders were specified as being in either industrialized or industrializing (a.k.a., “developing”) regions, though many were ambiguous in this regard. Broader entities were also mentioned, such as the electronics market and the economy. The most prevalent stakeholder group in this category was, of course, engineers due to the focus on engineering responsibility in the third essay question. Infrequently mentioned stakeholders in this category included scientists, businesspeople, sellers of electronics, and the electronics industry.

Like the Technical/Economic category, the Citizenry category also included specific groups, such as children and future generations, as well as broader entities like communities, the public, and society. Frequently, however, students used general indications of “people” or “humans.” Due to the focus of the assigned reading and the second essay question prompt, the most prevalent stakeholder group in this category was those people near the sites of e-waste recycling and/or disposal. Infrequently mentioned stakeholders in this category included farmers and affected people who were not part of the decision to recycle e-waste.

The Government/NGO category included the governments of both industrialized and “developing” countries, as well as broader indications of these countries (perhaps as a superset including both their governments and the citizens they represent). The most prevalent stakeholder

group in this category was “developing” countries. Infrequently mentioned stakeholders in this category included legislators, policy makers, non-governmental health organizations and regulatory groups.

The Natural Environment category was comprised primarily of general indications of the environment, though some students also used the term ecosystem. Infrequently mentioned entities in this category included the Earth, air/water, rivers/lakes, flora and fauna.

Table 9 summarizes the above categories and shows the number of participants who indicated one or more stakeholder in each. All students in this sample indicated at least one stakeholder in the Technical / Economic category in their responses to the third essay question. A strong majority indicated stakeholders in the Citizenry and Natural Environment categories; however, only about half of the students indicated stakeholders in the Governmental / NGO category. I examine these findings in terms of care-ethical responsibility in Section 4.4.1.

Table 9: Prevalence of Stakeholder Categories

Category	# of Participants who indicated one or more stakeholder
Technical/Economic	30
Natural Environment	29
Citizenry	28
Government/NGO	16

Table 10 summarizes the breadth of category coverage, showing how many participants indicated stakeholders in each number of categories. About half of the students mentioned stakeholders in all four of the above categories in response to the third essay question. About a third of the students mentioned stakeholders in three categories, and only a few mentioned stakeholders in two categories. No students indicated stakeholders in only a single category. I also examine these findings in terms of care-ethical responsibility in Section 4.4.1.

Table 10: Breadth of Stakeholder Category Coverage

# of Categories Covered	# of Participants
4	16
3	11
2	3
1	0

Comparison of Empirical Stakeholder Data with a Benchmark¹¹

Table 9 above provides one way of looking at the data; however, because its categories were inductively derived, it does not help us see the complete space of stakeholders involved in the e-waste problem and thus whom a care-ethically responsible response might consider. To gain better insight into potential holes in student knowledge, some kind of benchmark is needed. To this end, I present in Table 11 an authoritative stakeholder list created from the synthesis of two reports on the e-waste problem: one written with support from the Secretariat of the Basel Convention by the Swiss Federal Laboratories for Materials Science and Technology (EMPA) (see Schluep et. al 2012) and the other under a collaboration of the United Nations University (UNU) and the Solving the E-waste Problem (StEP) Initiative (see Wang et. al 2013). Note that these reports take a narrower definition of stakeholder than I have and thus consider the natural environment as a part of the system in which stakeholders operate rather than as a stakeholder in its own right.¹²

Mapping the empirically derived stakeholders from the student essays into the above categories reveals which stakeholder groups were acknowledged and which were missed by these students. Details of this mapping are presented in Appendix E (see Table 15) and the results are summarized in Table 12. Figure 9 depicts this mapping graphically with the stakeholder groups displayed

¹¹ Note: this sub-section on comparing with a benchmark was not published in Campbell & Wilson (2016).

¹² Laine (2010) explored how the natural environment has been positioned in the stakeholder literature and suggests explicitly treating it as part of the system in which stakeholders operate rather than as a distinct stakeholder because humans are a part of the natural environment. While I acknowledge this point, I have chosen to consider the natural environment as a stakeholder to draw more attention to it than I think it typically receives in engineering. In my view, moving the discussion in engineering from the natural environment as invisible and taken-for-granted to having stakeholder status is an important first step toward sustainability. More importantly, I think care ethics provides justification for treating the natural environment as a stakeholder because there are important, disadvantaged, non-human living things that have needs and risk being neglected otherwise, such as animal and plant species necessary for a healthy planetary ecosystem on which we all depend.

radially and shows the relative degrees of student coverage. Note that the categories are not mutually exclusive for a given essay and all participants indicated more than one type of stakeholder in response to the third essay question. Also, recall from Section 4.2.4a that this analysis only coded for stakeholders who were explicitly indicated.












Table 11: E-Waste Stakeholder List for use as Benchmark

Stakeholder Category from EMPA / UNU-StEP Report	Examples of Specific Stakeholders Included
Manufacturers & Importers	Engineers, Producers, Assemblers
Distributors	Retailers, Second-hand Markets, Charities, Online Distributors
Consumers	Individuals, Businesses, Governmental consumers
Collectors	Drop-off, Take-it-back, Municipal collectors
Refurbishers	Repair Shops, Service Centers
Recyclers	Dismantling, Separation, Materials Recovery
Downstream Vendors	Smelters, Jewelers
Final Disposers	Incinerators, Landfills
Most-Affected Communities	Communities neighboring sites of collection, refurbishing, recycling, and disposal
Civil Society	NGOs, International Organizations, Universities, Consultants
Governmental Agencies	Customs Office, Ministry of Commerce, Ministry of Finance

As Table 12 and Figure 9 show, the greatest coverage was in the category of Manufacturers & Importers (including engineers). This can be reasonably attributed to the focus of the essay question prompt on the responsibilities of engineers. The category of Most-Affected Communities also had a lot of coverage, likely due to the focus of the assigned reading on the human health impacts of e-waste recycling. However, only about half the students indicated stakeholders in the categories of Consumers and Recyclers, and, consistent with Table 9 above, only about half the students indicated stakeholders in the Government category, with just 6 indicating stakeholders under Civil Society (e.g., NGOs, international organizations, and universities). Furthermore, some key stakeholder groups were missed by most students, as very few indicated Distributors (e.g.,

retailers, second-hand markets, charities, and online distributors) or Collectors (e.g., municipal, drop-off, and take-it-back programs), and no students indicated Refurbishers (e.g., repair shops and service centers), Downstream Vendors (e.g., smelters and jewelers who buy from the recyclers), or Final Disposers (e.g., incinerators and landfills).

Table 12: Student Coverage of Benchmark Stakeholder Categories (n = 30)

Benchmark Stakeholder Category	# of Participants Indicating	Fraction of Sample
Manufacturers & Importers [includes Engineers]	28	 >90%
Distributors	3	 ~10%
Consumers	16	 >50%
Collectors	3	 ~10%
Refurbishers	0	 0%
Recyclers	13	 >40%
Downstream Vendors	0	 0%
Final Disposers	0	 0%
Most-Affected Communities	25	 >80%
Civil Society	6	 ~20%
Governmental Agencies	16	 >50%

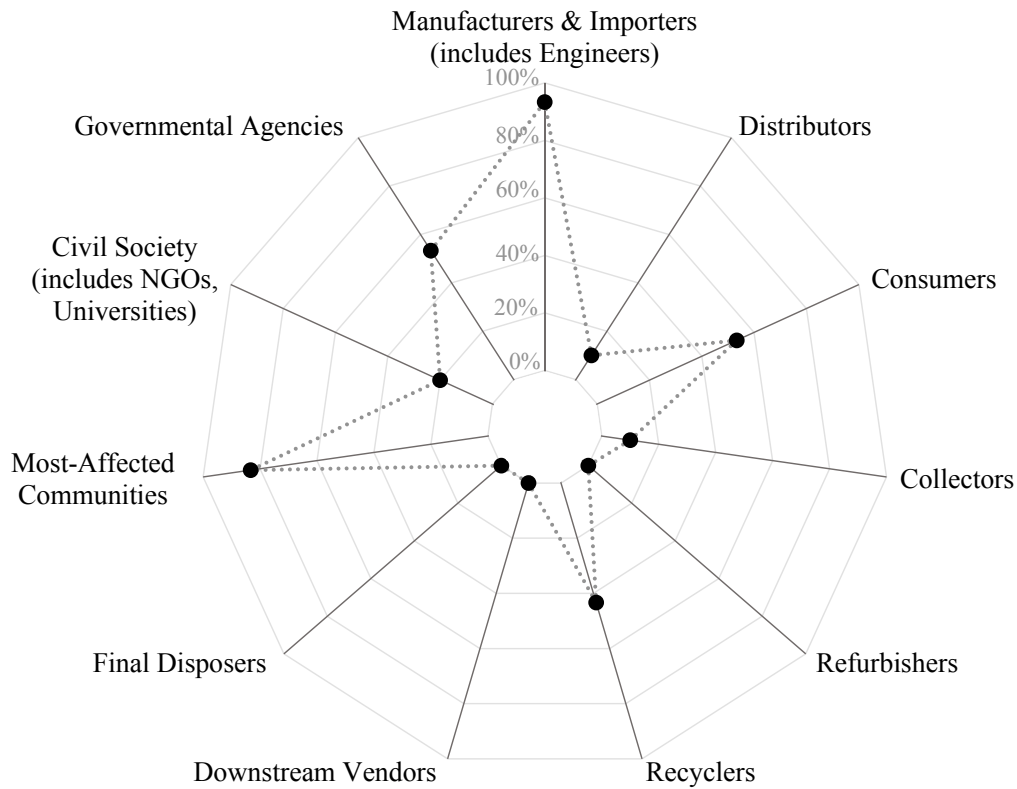


Figure 9. Student Coverage of Benchmark Stakeholder Categories
(Percentage of Students Who Indicated Stakeholders in Each Category, n = 30)

Some of these stakeholders, like Downstream Vendors, are rather obscure and perhaps easy to miss in this context because it is harder to imagine how engineering design changes could impact them directly. Some, like Collectors and Final Disposers, were implied in the writing of a handful of students¹³ and mentioned by a few in other parts of the essay outside their responses to the third question. However, it is somewhat surprising that a key stakeholder group like Refurbishers, who are very directly impacted by engineering design, was missed. It is common knowledge that electronics have become increasingly more difficult to repair due to design efforts toward miniaturization for the purposes of speed, efficiency, feature additions/improvements, and perhaps even planned-obsolence. Although most people in the U.S. have likely owned broken electronics that were easier to replace than repair, only one student in this sample even indicated the idea of electronics repair anywhere in his essay (as revealed by searching the full text of all

¹³ For example, see Jeremy's quote in Section 4.4.2a below, which mentions "collection, recycling, and disposal."

essays) and did so simply as an explanation for why e-waste was becoming so excessive, but not in relation to any suggestions to address the problem.

4.3.2. RESPONSIBILITY (DESCRIPTIVE CODING RESULTS)

This section presents the preparatory findings and a brief discussion of who engineering students associated with responsibility for the e-waste problem. Table 13 summarizes the passage-level findings, the codes for which were not mutually exclusive (i.e., multiple codes may have been applied to separate and/or overlapping passages in each essay). Further analysis that takes a more holistic view of individual essays is presented in Section 4.4.2, which explores the findings through a lens of care-ethical responsibility.

Table 13: Coding Results for Who is Responsible for the E-waste Problem

Code ^a	# of Participants
Engineers responsible	26
Others (non-engineers) responsible	22
Unclear in regard to engineers' responsibility	7
Unclear in regard to others' responsibility	1
Engineers not responsible (explicit)	0
Others not responsible (explicit)	0

^a Note: These codes were applied to passages and are not mutually exclusive in a given essay.

As indicated in the first row of Table 13, most participants were found to associate engineers with responsibility for the e-waste problem in some way. This was the expected outcome from the given prompt, which implicitly presumed that there were “ethical responses” engineers might take, and students in this sample did not explicitly challenge the prompt.

A somewhat unexpected finding appears in the second row of Table 13, which shows that, in spite of being asked specifically about the engineer’s responsibility for the e-waste recycling problem, twenty-two participants associated other entities and/or stakeholders with at least some of that responsibility. Further considerations of some of the non-engineering stakeholders/entities

students associated with responsibility are presented in Sections 4.4.2b and 4.4.2c (see also Campbell, Yasuhara, & Wilson 2012, for additional, though, preliminary insights).

As indicated in the third row of Table 13, some responses were unclear in their association of engineers with responsibility and/or unclear in their identification of engineers. These passages did not explicitly mention engineers and could, at most, be considered as implying engineer responsibility due to references to “companies” and “manufacturers.” Given the context and the engineer-focused prompt, such responses seemed to implicate higher-level management or policy rather than “in the trenches” engineers. These essays are noteworthy because they could be interpreted to indicate resistance to responsibility assumption (e.g., deflecting responsibility from engineers to others) and/or represent conceptions of engineers as lacking agency or power to act. Selections from these essays are considered in Section 4.4.2.

As indicated in the fourth row of Table 13, one response was unclear in its association of others (non-engineers) with responsibility for the e-waste recycling problem. While it explicitly mentioned non-engineering stakeholders, I could only consider this instance (and the essay in which it appeared) to imply the responsibility of non-engineers. Note: because the prompt focused on the responsibility of engineers, I included this code primarily for the sake of completeness.

As indicated in the fifth row of Table 13, no participants in the present sample explicitly absolved engineers of responsibility for the e-waste problem. Such a response would have been surprising because it would directly challenge the assumption of engineer responsibility that is implicit in the essay question prompt. The code was included because previous analysis of data from an earlier offering of the course contained some student writing that challenged the implicit assumption of engineer responsibility (see Campbell, Yasuhara, & Wilson 2012). However, in the present sample, explicit disavowal of engineer responsibility was not found.

Finally, as indicated in the sixth row of Table 13, no participants in the present sample explicitly absolved non-engineers of responsibility for the e-waste problem. This was expected, because the prompt focused on the responsibility of engineers. I also included this code primarily for the sake of completeness.

4.4. FINDINGS (IN CARE ETHICS FRAMEWORK)

In this section, I tie the coding results from Section 4.3 back to the Responsibility element of the adopted care ethics framework (see Section 4.1.2), and then illustrate this with quotations from student writing.

Recall that Tronto's framework suggests that after someone becomes aware of a need (which is covered under the concept of Attentiveness), they must decide (a) whether they are in some way responsible for addressing it, and (b) if so, how they should respond (Tronto 1993, p. 106). These decisions are both covered under the concept of Responsibility, and the first of these decisions has been illustrated using the writing of engineering students on the topic of "backyard" e-waste recycling in Section 4.3 above (the second is planned for future work - see Section 4.5.3).

It is helpful to ask at this point: what would "good responsibility" look like in the e-waste recycling situation? Or more specifically, what would engineers do to assume care-ethical responsibility well? For example, what approaches would engineers use and what attitudes would they have? How and why would they do what they decided to do? What would be their motivations? Whose needs and perspectives would be considered? Of course, this data set cannot speak to all of these questions because students were explicitly prompted only for what engineers should do, not the details of their approaches, attitudes, or motivations. Nevertheless, a careful reading of student responses in context reveals nuances that speak to some of these questions, especially those dealing with awareness of stakeholders and manners of assuming responsibility, both of which are explored further below.

4.4.1. STAKEHOLDERS (IN CARE ETHICS FRAMEWORK)

Given the magnitude and complexity of the e-waste problem, a number of stakeholders might be considered responsible because they have a direct influence on the situation. As suggested in Section 4.1.1, a conventional ethical perspective concerned with assigning blame would focus on causal responsibility, which can be found across the lifecycle of electronic devices from design engineers and electronics companies, to consumers and eventual disposers of electronic devices. Adopting a care-ethical perspective helps spotlight stakeholders who are affected by the situation

as well, such as the innocent people, flora, and fauna living near “backyard” e-waste recycling facilities who are being harmed by the resulting pollution. Clearly, many stakeholders are involved and will need to be involved in any realistic attempts to address the problem. Most of the students were aware of this, as indicated in the second and third rows of Table 13, which showed that a majority of the students associated both engineers and others (non-engineers) with responsibility for the issue. Nonetheless, I found variations in the degree to which student responses were likely to be effective in addressing the problem based on two possible measures of care-ethical responsibility: considerations of multiple/varied stakeholders and considerations of disadvantaged stakeholders (such as those who are vulnerable, powerless, or underprivileged) and their needs. These measures are explored below.

4.4.1a. Multiple/Varied Stakeholders

A first order assessment of the sophistication of student thinking might be that the greater the number of relevant stakeholders considered in reply to the third essay question the better (i.e., more care-ethically responsible) the response. Responses that indicated both influencing and affected stakeholders would be deemed more care-ethically responsible than those that mentioned stakeholders in only one direction of influence. Similarly, those responses that indicated non-engineer stakeholders (e.g., governments, communities, corporations) working with (or sometimes instead of) engineers would be more responsible than those that failed to mention non-engineering stakeholders at all. One student, Mason, provided a case of non-engineering breadth when addressing the third essay question, writing about the responsibilities of a variety of stakeholders, including device manufacturers, consumers, and governments:

“Manufacturers of electronic devices have the ethical responsibility to produce low impact products and to offer to recycle outdated devices for consumers. However, manufacture[r]s listen to the consumer and since consumers desire the least expensive products, the most financially cost effective method of production is used. If consumer awareness rose then perhaps consumers would send manufacturers a different message. Some countries in Europe have already set standards for safe disposal of WEEE [waste electrical and electronic equipment]. For example, the EU [European Union] has a Directive to limit the chemicals that can be used in the recycling process called Restrictions on Hazardous Substances – RoHS. Developing countries are much farther behind in their regulations, especially in the enforcement thereof. Enforcement could come in many forms. A positive method would be for governments to give kickbacks to companies and consumers who choose to seek responsible recycling means. A negative method would be to monitor production of electronics, the recycling methods used and the disposal method of consumers.”

Mason's response demonstrates some of the broad knowledge of key human stakeholders necessary to address the problem, and was one of the most prolific in terms of number of different stakeholder types indicated. This is in contrast to those essays that mentioned only a few human stakeholders, such as that of Chetan, who mentioned only engineers and consumers of electronics:

"Engineers are partially accountable and should be employing design techniques which minimize waste. Certain electronic devices should be designed with quality components in order to maximize life and prolong replacement. [...] Providing consumers with long-lasting, reliable electronics will limit the opportunity for replacement."

The examples from Mason and Chetan above suffice to illustrate the variation in the number of stakeholders who were considered. As indicated previously in Table 10, although all students in this sample mentioned stakeholders in two or more categories in their responses to the third essay question, many indicated stakeholders in all four categories. This is encouraging from a care-ethical perspective, though there is clearly room for improvement, because nearly half the students did not consider key stakeholders in the government/NGO category (see Table 9).

4.4.1b. Disadvantaged Stakeholders

Some stakeholders influence the situation while others are only affected by it, some are in positions of greater vulnerability than others, and some have more power than others to make changes. When engineering students considered disadvantaged stakeholders (e.g., those who are vulnerable, powerless, and/or underprivileged), they were likely to be expressing more responsibility in a care-ethical sense than those who considered only powerful and privileged stakeholders. In the students' essays, I found a variety of disadvantaged stakeholder groups mentioned. In this sub-section, I discuss three of these groups: (a) the working class, (b) people near "backyard" recycling facilities, and (c) future generations. These groups were chosen because they were among the most commonly mentioned and the quotations comprising them were relatively clear and compelling. Other disadvantaged groups mentioned included children, ecosystems, and the flora and fauna near sites of "backyard" e-waste recycling and disposal, but these quotes proved less useful in understanding perceived responsibility and are therefore not discussed in detail.

The Working Class

Several students demonstrated care-ethical responsibility with regard to disadvantaged stakeholders by considering the needs of the working class. For example, Shota associated engineers' responsibility with the job needs of "backyard" recycling facility workers:

"The goal for the engineers to solve an ethical issue is to satisfy all the stakeholders. Thus the goal for this issue is firstly to minimize the health problem, and secondly to maintain the existence of the facilities so that the workers will not lose their jobs."

A counterexample of care-ethical responsibility for the working class appears in the writing of another student, Na, who wrote about designing for parts reuse and indicated manufacturing workers indirectly. However, in this case, her considerations were focused not on the needs of laborers, but on protecting the natural environment and improving economic efficiency for the manufacturing companies:

"[...] Thirdly, making the whole components of electrical or electronic equipments recycling [*sic*] [*recte* equipment recyclable] and can be used for [*sic*] many times. For example, one component in one [piece of] electrical equipment can be used in another [piece of] equipment. This will not only save the resources and protect the environment, but also be more economics [*sic*] and save labor force."

In comparison with Shota's quote, which better demonstrated care-ethical responsibility for the working class, Na's quote serves to remind us that it is not enough just to mention relatively disadvantaged stakeholders: care-ethical responsibility also means considering their needs and perhaps giving a higher priority to those stakeholders who are disadvantaged in terms of vulnerability, power, or privilege. However, Na's quote also draws attention to another issue: that of prioritizing competing needs. For a given solution, how should the environmental impacts, economic benefits to manufacturers, and livelihood needs of employees be balanced and considered together?

People Near "Backyard" Recycling Facilities

Given that the provided reading and essay questions specifically called out the human health impacts of e-waste recycling in China and India, it comes as little surprise that many students mentioned the people living or working in and around "backyard" recycling facilities in their

responses to the third essay question. For example, Sophia, after suggesting that everyone (not just engineers) shared responsibility for the problem, wrote:

“The impact of WEEE’s improper recycling and disposing is harmful to everyone near the operation.”

Similarly, Carlos wrote:

“Overall it is clear that waste electronic recycling can greatly affect human life in areas contaminated by the byproducts of recycling. As engineers, it is important to consider how these problems can be solved.”

Jacob, in addition to the livelihood needs of the “backyard” recycling facility workers mentioned above, also wrote about the needs of people near recycling facilities, including farmers and other people affected by the resulting pollution:

“Farmers and communities will need to be relocated. The inhabitants of the affected communities will need to be examined and treated.”

Also, following a discussion of the “neighboring population that did not originally agree” (see Isabella’s second quote in Section 4.4.2 below), Isabella clarified these are innocent people being wrongly affected:

“[T]he ability for by-products to travel long distances and negatively impact the health of innocent others should not be allowed and therefore needs to be monitored.”

It is perhaps the innocence of these people that makes them particularly vulnerable and disadvantaged. When practicing good care-ethical responsibility, we should not only include these stakeholders’ needs in our considerations, but should even prioritize them because of their vulnerability.

Future Generations

Finally, I identified a third example of care-ethical responsibility with regard to disadvantaged stakeholders in the writing of several students who indicated future generations. For example, Mason wrote:

“The ethical responsibility lies with all who participate in the use of electronic circuits to dispose of the old with foresight and respect for future generations.

Similarly, Putera wrote:

“For the future of our generations, the electronic industry needs to be re-evaluated.”

Compared to the innocent neighboring populations that Isabella mentioned (see above), future generations are perhaps even more disadvantaged by virtue of their complete lack of power to influence the present situation. When practicing good care-ethical responsibility, we would not only include these stakeholders’ needs in our considerations, but would even prioritize them because of their disadvantage.

From the perspective of care-ethical responsibility, these three examples of disadvantaged stakeholders (i.e., the working class, people near “backyard” recycling facilities, and future generations) are encouraging. Indeed a majority of the students indicated one or more disadvantaged stakeholder. However, some students in this sample did not indicate disadvantaged stakeholders other than the natural environment in response to the third essay question. While such absence could potentially be due to the terse and direct writing styles of some engineers, it could also suggest an attempt to disassociate the “real,” technical engineering work from what they perceive to be merely contextual factors that are beyond the purview of engineering (cf. content knowledge and the engineering problem-solving method in Leydens & Lucena 2007).

4.4.2. ENGINEERS’ RESPONSIBILITY (IN CARE ETHICS FRAMEWORK)

In this section, I look at the ways in which engineering students acknowledged (or neglected to acknowledge) the responsibility of engineers for the e-waste recycling problem. While most students associated engineers with responsibility for the e-waste problem (Table 13), the degree to which they did so varied and is described in more detail in Table 14. Over half of the students associated both engineers and non-engineers with (shared) responsibility for the problem. This suggests that most students held realistic views of the situation and recognized, to varying degrees, the complexity of the problem. In fact, some students even recognized the need for engineers to

interact or collaborate with others in effectively addressing the problem (though formal analysis of the indicated types of interactions is beyond the scope of this work). In contrast, four essays were everywhere ambiguous with respect to engineers' responsibility for the e-waste problem. This ambiguity was due either to a lack of clarity in identifying stakeholders (e.g., using the words "companies" or "manufacturers" to imply engineers) or to neglecting to mention or even imply engineers in their responses thereby associating only others (non-engineers) with responsibility. These essays are noteworthy because they present interesting minority perspectives on the issue. In the sub-sections that follow, I discuss each of these four different manners in which students acknowledged the responsibility of engineers: (1) without qualification/ limitation, (2) shared with others (without qualification/limitation), (3) shared with others but qualified or limited, and (4) ambiguous with respect to engineer's responsibility.

Table 14: Essay-level Results for Acknowledging Engineers' Responsibility

Manner in which Engineers' Responsibility Acknowledged^b	# of Participants
Without Qualification/Limitation	7
Shared with Others (without qualification/limitation)	10
Shared with Others but Qualified/Limited	9
Ambiguous (with respect to engineers' responsibility)	4

^b These categories were applied at the essay level and are mutually exclusive.

4.4.2a. *Responsibility: Without Qualification/Limitation*

Seven student essays explicitly acknowledged the responsibility of engineers without any qualifications, limitations, or association of other stakeholders with responsibility. Some expressed very firm conviction, such as the following declaration by Jeremy:

"Engineers, above all else, are accountable for proper collection, recycling and disposal of WEEE [waste electrical and electronic equipment]. Therefore, they must take a responsible and a[n] integrated approach to this issue."

Others were perhaps less imperative, but still clearly indicated that engineers held responsibility, such as Feng, who wrote:

“I think modern engineers producing these electronic technologies should turn their eyes to the environmental impact that dumping the electronic waste has brought about. They should pay more attention to the environment and realize the significance of environmental protection.”

While the association of only engineers with responsibility could indicate a somewhat naïve and simplistic view of the situation (e.g., as if engineers alone could solve such a complex problem), note that the prompt asked specifically for ethical responses of engineers producing electronic technologies. Some students may thus have chosen to limit the scope of their responses to that of engineers’ responsibility and intentionally excluded consideration of other responsible stakeholders and entities.¹⁴

4.4.2b. *Responsibility: Shared with Others*

Ten of the student’s essays acknowledged the responsibility of engineers without any qualifications or limitations while also pointing out that this responsibility was shared with other stakeholders. Several of these essays included notions that “everyone” was responsible and then went on to specify stakeholder groups, such as consumers, distributors, manufacturers, and design engineers. For example, Sophia implicated everyone involved in the creation and use of electronics when she wrote:

“When faced with such a problem as the quality of human life, it is easy to point the finger and say “they didn’t do enough” or “they should be held accountable”, but in reality it is the responsibility of everyone involved: this is everyone from the engineers who designed the electronic, to the producers, to the sellers, to the consumers and everyone in between.”

Several essays were less broad in attributing responsibility to others, indicating a few specific stakeholder groups, such as electronics companies or governments. For example, Santiago associated the people/governments of technologically advanced countries, electronics manufacturers, and engineers with responsibility when he wrote:

“As mentioned above, countries that are able to produce highly technical electronic devices should be held accountable to the waste that is created from the product. Technology is rapidly increasing and

¹⁴ As a case in point, Sophia explicitly indicated that she did this when she wrote: “*Though it is possible to speak about the “ethical” responsibilities of everyone involved, this paper will focus its attention on the efforts of engineers, the masterminds and first line of responsibility in the creation and distribution of these electronics.*”

due to this rapid increase, there is more of a build-up in hazardous waste. I think that manufacturing companies should hold more responsibility to how their products are being recycled. [...] As a future engineer, I think that we should be more responsible with how the product we engineer is created and how we should take into account the best procedure to properly recycle it.”

There were two essays that associated non-governmental organizations (NGOs) with responsibility: those of Arnav and Atian. Arnav implicated health organizations in this quote:

“It is vital for engineers and health organizations to attend to this situation and dedicate sufficient resources to help solve this persistent situation.”

Atian, on the other hand, suggested that engineers work with business people and others in the industry to set up a regulatory group:

“In the area of waste electronics, engineers need to have integrity by stopping illegal exports [...] Engineers need to be committed to making sure wasted products are not dumped in Africa or burned in India; this will only happen if as a global community, engineers and businessmen work together to preserve our natural resources and better humanity. This goal may be achieved by setting up a group for professionals in the industry that regulates and promotes safe recycling.”

Finally, two essays associated scientists (in addition to engineers) with responsibility for the problem. For example, Ying wrote:

“Scientists and engineers should be concerned about [...] how to control the spread of toxic substances during the electronic recycling.”

4.4.2c. Responsibility: Shared with Others but Qualified/Limited

Nine of the student’s essays acknowledged engineers’ responsibility as shared with other stakeholders, but placed limitations, constraints, or qualifications of some kind on engineers’ responsibility. Five of these essays indicated that engineers’ responsibilities for the problem were contingent upon other factors, such as governmental regulations, support from employers, and/or economic constraints. For example, Wyatt felt that product-design related changes like using biodegradable materials was “about as far as” electronics engineers can go, but that this could help legislators enact better e-waste disposal regulations:

“The above steps in making a device as easy as possible to recycle is about as far as the engineers

designing the[m] will be able to go to facilitate the device's ultimate responsible disposal. However, by making the entirety of the device more economical to recycle, the engineers making these decisions may help legislators establish more stringent and effective environmental controls governing the disposal of e-waste.”

Bao’s response below seemed to imply that consumers and the market economy also shared some responsibility for the problem, and he mentioned materials-cost constraints as limiting the options of modern engineers. He then singled out materials engineers as being able to help ease this limitation:

“Due to [the] market and the requirement[s] of customer[s], modern engineers are hard to find [sic] different, efficient material[s] that can replace the current material[s]. [In] my opinion, material[s] engineers can do a lot to help a better future of [e-waste]. They are [the ones] who will invent, [and] find out the better and recycling [sic] materials that can replace the modern materials.”

Note that Bao’s response was written in a more optional tone than most, indicating that engineers can or could be involved but nowhere using words that suggested duty, obligation, or responsibility (e.g., should or must).¹⁵

In the other four essays in which responsibility was acknowledge and shared but limited, I observed expanded or diffused notions of responsibility that took the focus off of engineers to varying degrees. For example, Lizzie wrote of the engineers’ responsibility as an extension of corporate responsibility:

“I believe that engineers can help solve some of the issues with electronic waste. As the people who are designing products that are being consumed at high volume, it is the company who produces the products, and by extension, the engineer’s duty to observe and adjust design to avoid negative consequences of their work.”

A more extreme case of diffusion appeared in the essay of Chloe, who associated both engineers and non-engineers with responsibility for the e-waste problem, but neglected to provide any indications of ways in which engineers might exercise their responsibility. Her initial statement that engineers are directly responsible seemed straightforward:

“The engineers producing these hard-to-dispose-of electronic materials should have full accountability

¹⁵ See discussion of “can”, “could”, versus “should” under “Coding for Who is Responsible” in Section 4.2.4a.

for the effect the materials have on the environment. If the engineers were not designing these materials, disposal would not be an issue.”

However, her next sentence appeared to deflect responsibility away from engineers, assigning it instead to the companies for whom they presumably work:

“That being said, the companies responsible for producing these materials should be held fully accountable for the impact of their products.”

Her next two sentences then focused on what the companies should be required, presumably by some government or regulatory agency, to do:

“When it is discovered that a company’s products are, in effect, destroying an ecosystem, the company must be required to first, either change the manufacturing process of their products that results in such devastating consequences and/or be required to implement a recycling system that all potential customers have access to, so products do not get disposed of in ways that would be harmful to the ecosystem. If no manufacturing changes can be implemented and a recycling system cannot be found, the company should not be allowed to continue making their products [...]”

Other than what might be implied by the above statement for engineers to actually do (i.e., change manufacturing processes and/or implement recycling systems), engineers’ avenues for assuming responsibility appears to be limited or constrained by the decisions of the companies for whom they work. While this essay would benefit from revision to clarify the author’s apparently contradictory position, as currently written, it might indicate resistance to responsibility assumption (e.g., deflecting responsibility from engineers to others) and/or suggest a conception of engineers that is lacking in agency or power to act independently. This idea is explored further in the following sub-section.

4.4.2d. Responsibility: Ambiguous or Absent

Four essays were ambiguous with respect to the responsibility of engineers for the e-waste problem because the word engineer did not appear anywhere in the essay. Some of these essays contained only references to the “companies” and “manufacturers” for whom engineers presumably work, and some of these essays did not even imply engineers through use of the word design. Like Chloe’s writing above, these essays are potentially noteworthy because they may

indicate resistance to responsibility (e.g., deflecting responsibility from engineers to others) and/or conceptions of engineers as lacking agency or power to act. For example, Olivia suggested that everyone, namely companies, governments, and customers, should do their part, but nowhere identifies engineers explicitly, nor does she suggest specific actions engineers might take:

“As the electronics world continues to prosper and grow, the need for safer recycling practices is becoming more immanent. Companies rarely take into consideration what happens to their products in the longer term. Harmful toxins are released into the atmosphere and are harming human and environmental health as a result of bad recycling practices. As time goes on and the electronics market continues to grow, companies, governments and customers must strive to reduce the harsh toll that waste electronics recycling has. There are safe ways to dispose of electronics and everyone must do their part to practice these better techniques.”

Ananya’s essay also completely neglected to mention engineers explicitly, instead associating the manufacturers/companies for whom they presumably work with responsibility for the e-waste problem (here engineers may be implied by use of the word design). Specifically, she suggested that governmental policy/law would be necessary to enforce manufacturer accountability through the use of RFID tags:

“One way to solve this problem might be [...] forced corporate responsibility to have the manufacturers design product[s] which are easier to recycle of [sic] get rid of. [...] They need to be responsible of [sic] the way their products could end up as the [sic] threat to the environment just the way they [are] responsible for if the products are not safe for consumers. [...] One way that we can do forced the manufacturers to install radio frequency identification (RFID) tags to the pieces of electronics to make it possible to tract down the manufacturer of the product.[...] This solution, however, would need for the government to pass a law that stated that all products sold in the us should be tagged to ease the process of treatment and all company should be responsible of taking back and properly treat their devices after at the end of product life because this responsible on the company will drive them to design the products to be easier to use and reinvent the treatment process to be better and cheaper.”

The response of one student was surprising. Despite the essay question requesting ethical responses of modern engineers producing electronic technologies, Isabella felt that responsibility lies with the people who are actually recycling the waste since they are choosing to harm themselves and their own environment:

“It is up to the people living in the area how they want to go about recycling their electronic wastes so that it has minimal ethical implications on themselves and their environment alike.”

She then went on to explain how “backyard” recycling becomes unethical when innocent bystanders are affected, but still neither mentions nor implies engineers:

“However, when it begins to start effecting a population that was not a part of the decision, then it is not right. Because these byproducts can be transported from their city or living area to any other area via being lifted into the air and carried in the wind, this is not fair to the neighboring population that did not originally agree with the methods of disposing their electronic waste and have their own set of standards to follow. When a group of people have a majority vote and decide how to go about poisoning their environment and affecting their own health with their waste, then that is fine with them. As soon as this decision has ramifications negatively impacting others who were not a part of the decision, it is neither an ethical nor a feasible solution.”

Thus, it would appear that Isabella did not see a relationship between the engineers designing and manufacturing electronic equipment and the eventual disposal/recycling of this equipment by others. Her essay might also suggest an underdeveloped sense of environmental ethics, for while she understands some of the environmental justice issues associated with e-waste recycling harming innocent people, her essay does not demonstrate care about the natural environment as having either intrinsic value or instrumental value to future generations.

The other student who neglected to mention engineers in association with responsibility, Jacob, also did not appear to see a relationship between the engineers designing and manufacturing electronic equipment and the eventual disposal/recycling of this equipment by others. For him, the problem was largely a matter of governmental regulation and control:

“To resolve the issue, more oversight is necessary. First of all, the illicit dumping needs to be policed, especially along major rivers and lakes. Finding and shutting down illicit recycling centers should be a priority in the short term. If agencies are able to shut down the existing sources of pollution, it will halt dumping [...]”

In addition to immediate regulatory actions, Jacob also demonstrated knowledge of some of the broader social complexities involved, such as maintaining jobs for existing workers (see Section 4.4.1b). He then went on to write about long-term clean-up of existing pollution, showing a sense of concern for both humans and the ecosystem. He then concluded with the following summary of an ethical response to the e-waste problem:

“Governmental agencies should not only halt illicit dumping, but develop a long term solution to repair local ecosystems and communities, monitor the safety of food supplies, and construct facilities with

strong oversight that will properly recycle electronic waste.”

Now, one might argue that engineers would have to be involved in developing solutions to repair ecosystems, monitor food safety, and construct and operate new recycling facilities, and Jacob may have had reasons for explicitly leaving engineers out of the discussion. However, based on what was written, his response seems to absolve engineers of the responsibility to develop solutions unless mandated or employed by the government to do so.

Thus, what we saw when students neglected to mention engineers, seemingly absolving them of responsibility for the global e-waste problem, was not a single position or reason why. Instead, students in this category had a variety of reasons for reducing or eliminating the engineer's responsibility.

4.5. SYNTHESIS AND IMPLICATIONS

In this section, I synthesize the findings and explore possible implications, including suggestions for future work.

4.5.1. SYNTHESIS OF FINDINGS

Given the relatively small size of the sample and the interpretive nature of the work, this brief synthesis of the findings is best viewed as *moderatum* generalizations (Williams 2000; Payne and Williams 2005), in which both the scope of the claims and the degree to which they are held are appropriately moderate. Because the paper uses empirical findings to scaffold conceptual exploration, the nature of *moderatum* generalizations that can be reasonably drawn will also vary. Specific comments on the limitations of the empirical findings are described in the last paragraph of this sub-section.

The coding results indicated that nearly all students considered stakeholder groups that I inductively categorized as technical/economic, environmental, and citizenry, but only about half the students mentioned governmental or non-governmental organizations (Table 9). This suggests

a need to help students understand the roles and potential contributions of governments and NGOs when working with engineers to address the e-waste problem. When benchmarked against a more detailed, authoritative stakeholder list from the literature¹⁶ (Table 11), several other trends became apparent (Table 12 and Figure 9), most notably that a key stakeholder group seems to have been completely missed: Refurbishers (e.g., repair shops and service centers) were not mentioned by any participants and the idea of repair appeared in the writing of only one student. This is somewhat surprising given the ubiquity of electronic products in the U.S. that are easier to replace than repair (thus generating more e-waste), and given that product reparability is so obviously impacted by engineering design. This finding can perhaps be explained by a cultural trend in American society (of which all students in this study were arguably a part by virtue of their attending a U.S. university) to prefer new, innovative, and fashionable electronics rather than to consider repair (see McCollough 2010), thus creating a cultural blind-spot for Refurbishers and their considerable role in addressing the e-waste problem.

Looking at these findings through a care-ethics lens, (Section 4.4.1), I identified two possible measures of care-ethical responsibility as indications of the relative quality of responses: multiplicity/variety of indicated stakeholders, and consideration of disadvantaged stakeholders and their needs. Multiplicity/variety of stakeholders is an aspect of care-ethical responsibility that provides ties back to Attentiveness in Tronto's care ethics framework and increases the chances that disadvantaged (e.g., vulnerable, powerless, and/or underprivileged) stakeholders will have their voices heard and their needs met. Even more generally, human stakeholder awareness could be considered a first step towards broader awareness of the direction of a stakeholder's influence (i.e., influencing and affected) that includes not only human stakeholders but also environmental/ecological entities that may be involved. Note, however, that the sheer number of different stakeholders considered does not necessarily make a given response more care-ethically responsible than another: it simply increases the likelihood that this will be the case. It is possible to consider many stakeholders, but miss those who are in most need of consideration.¹⁷ Thus, the

¹⁶ Note: this material on comparing with a benchmark was not published in Campbell & Wilson (2016).

¹⁷ It is also possible (though perhaps less likely) to hone in on disadvantaged stakeholders to the exclusion of all others, which serves to highlight the potential danger of partiality (e.g., parochialism or only addressing local needs) that is present in care ethics (see Tronto 1993, p. 142 and 146). However, as observed in the Introduction of Chapter 1, while care ethics might not be the only ethical framework that needs to be employed in a given

best (i.e., most care-ethically responsible) responses will also draw appropriate attention to specific stakeholders (and their needs) who are in some way disadvantaged compared to other stakeholders.

Coding also revealed that most (though not all) of these engineers of tomorrow associated engineers with responsibility for the e-waste problem (Table 13) in some way (Table 14). Furthermore, in spite of being asked specifically about the responsibilities of engineers for the e-waste recycling problem, many participants associated other entities and/or stakeholders with at least some of that responsibility. Looking at these findings through a care-ethics lens (Section 4.4.2), I identified a third possible measure of care-ethical responsibility: manner of acknowledging responsibility. Here I examined variations in the ways in which students acknowledged engineers' responsibility and categorized them as: (a) acknowledging (possibly sole and complete) responsibility for the problem, (b) sharing responsibility with other stakeholders, and (c) acknowledging limited responsibility for the problem.

At first glance, the notion of sharing responsibility with others might seem to strike an Aristotelian "golden mean" between the extremes of over-committing and diffusing or deflecting responsibility; however, even within each of these extremes, one can find both good and bad facets of care-ethical responsibility that are informative. For example, while the mindset of unreservedly acknowledging one's responsibility could be a sign of naivety leading to unworkable solutions, it may also evince a positive willingness to help (in spite of not really knowing how to do so) that is more likely to contribute creative ideas through its optimistic "find-a-way," "can-do" attitude. Alternatively, while the mindset of placing limitations on the scope of one's responsibility could be conservative or evasive, it may also reveal a sense of realistic awareness of one's own power for action (and its limitations or constraints) that would encourage collaboration with others who are in better positions to help. In other words, this shows the following attributes of responses that are more (and less) care-ethically responsible: (a) they are motivated by positive willingness to help (rather than defensive "that's not my job" attitudes), (b) they involve sharing responsibility in ways that encourage openness and collaboration (rather than either setting arbitrary boundaries

situation "a moral theory that can recognize and identify these issues [e.g., privilege, paternalism, parochialism] is preferable to a moral theory that, because it presumes that all people are equal, is unable even to recognize them" (Tronto 1993, p. 147).

or trying to do everything oneself), and (c) they incorporate mature awareness of limitations and constraints, and of the abilities and capacities of oneself and others (rather than taking an unreflective approach that ignores these considerations).

I also observe that these three measures of care-ethical responsibility (i.e, multiplicity/variety of stakeholders, consideration of disadvantaged stakeholders, and manner of acknowledging responsibility) provide ties forward to the third element of Tronto's framework, Competence, impacting the likelihood of good "care-giving." In other words, the act of assuming care-ethical responsibility can be viewed as a form of planning (i.e., "this is what I'm going to do, and this is how I'm going to do it"), which is suggestive of the potential or promise for care-ethical competence. Deficiencies in such planning would lead to ineffective actions and unpromising solutions. While it is beyond the scope of this empirically-based article to attempt a comprehensive philosophical treatise on the topic, I provided here a brief synthesis as a first step toward better understanding care-ethical responsibility in the context of engineering and the problem of e-waste recycling/disposal.

4.5.2. LIMITATIONS

Before moving in to the study's implications, some notes on limitations of the empirical findings are in order. First, recall that this study examined a relatively small, intentional sample of student responses to the e-waste recycling problem. This sample was chosen to maximize the demographic diversity in the available data to reveal perspectives from a broader set of backgrounds, cultures, and life experiences, thus diversifying the findings compared to trends obtained from purely random sampling. Note also that the analysis sought to cover the breadth of responses rather than to reveal statistically significant trends because the purpose of the study was descriptive and exploratory. Any interpretations of the findings with respect to trends and prevalence must be made judiciously. If widely generalizable results are sought, the findings from this work can be used to inform the larger, quantitative or mixed-methods studies that would be needed to achieve the statistical power and confidence necessary for broader generalizations. The present work provides useful constructs, ideas, and suggestions to inform such future work. Also note that the essay prompt implied engineer responsibility (rather than freely soliciting for a list of

responsible entities) and that ascriptions of responsibility to non-engineers were not the primary focus of this analysis.

A possible limitation of the study is that the students who contributed their writing to this project received neither priming nor instruction on the topics of care ethics or ethical responsibility before or after completing of their essays. Prompting students for their thoughts on an “ethical response” to the e-waste recycling problem was, I feel, a reasonable way to approach the topic in lay terms. Furthermore, by not seeding ideas of care-ethics and responsibility in students’ minds, the findings of this work provide a base line, indicative of where students are starting from in terms of care-ethical responsibility that can be used to inform educational materials and experiences that are developmentally appropriate (i.e., within the Vygotskian “zone of proximal development.”)

Due to the optional nature of the assignment, another possible limitation of the study is self-selection bias. However, the effect of this bias cannot be assessed and one can only conjecture. For example, if the students were motivated primarily by the desire for extra-credit points, then the sample would likely neglect the perspectives of students who either felt they were doing well in class or were apathetic about their grades. The significance of such bias with respect to care-ethical responsibility is not clear. However, if students were motivated primarily by the choice of topic (i.e., social / environmental impacts of technology), then one possible effect of self-selection bias might be to over-emphasize the level of engineers’ responsibility reflected by the sample relative to that of the population. Note, however, that self-selection bias need not devalue or invalidate this study, since no claims of statistical significance are being made in this qualitative analysis, and while the transferability of the findings may at first appear somewhat limited, self-selection based on topical interest would serve to focus the analysis on an important group: those who care about the social / environmental impacts of technology. It is these students who, through the intrinsic motivation that caring provides, are likely to be the future drivers of change influencing tomorrow’s technology. If some of this group show evidence of care-ethical responsibility, as operationalized in this analysis, this is encouraging news indeed; however, if others in this group evince a need to improve in care-ethical responsibility, not only would this identify a serious problem (especially if these are the most care-ethically promising future engineers), but it would also provide insights into how to go about addressing it.

Finally, I should point out that the assignment used to generate the data was not created with Tronto's care ethics framework explicitly in mind; we (my primary advisor and I) relied on a broad, intuitive understanding of care ethics and social justice to create the assignment (though ideas of humanitarianism and engineering ethics were explicit in our thinking at the time). Nevertheless, the elements of Tronto's framework have proven useful for interpreting and assessing the resulting student work, and thereby supporting conceptual explorations of care ethics in this context. There is also a possible benefit to this approach in terms of reducing confirmation bias during data collection (i.e., the danger of prompting the participants in such a way that influences responses in support of the researchers' a priori hypotheses). Confirmation bias during the application of the care ethics framing (Section 4.4), however, is acknowledged as a possible limitation of the study, since the data chosen in this phase of the analysis were selected specifically to illustrate care-ethical responsibility, rather than to identify other forms of responsibility or assess their prevalence. However, given the purpose of the work to introduce and highlight care-ethics, as well as the qualitative and exploratory (rather than confirmatory) nature of the study, I hope the reader will agree this is not problematic.

4.5.3. IMPLICATIONS

In this sub-section, I explore some of the implications for engineering education (including practical suggestions that apply to a variety of learning environments), empirical educational research (especially future work), and engineering ethics including suggestions for educational policy and the practice of engineering.

4.5.3a. Implications for Teaching and Learning Engineering

As shown in Table 9, Table 12, and Figure 9, student awareness of some of the key stakeholders involved in addressing the e-waste problem (e.g., governmental organizations, NGOs, and repair shops) appears incomplete. To be part of the solution rather than part of the problem, engineers will need to consider how their work potentially impacts all stakeholders. This data suggests a need to raise awareness about how engineers might work with governments and NGOs in addressing the problem. It also suggest a need to raise awareness about many of the downstream

stakeholders and processes that handle electronic devices as they reach the end of their useful lifetimes. Opportunities for engineering solutions are present in relation to many of the stakeholders the students did not think of, such as those associated with repairing or refurbishing electronics to extend product lifetimes and thereby reduce the volume of e-waste. While a small handful of students wrote about these issues in terms of the processes involved, very few indicated the associated stakeholders. Awareness and knowledge of the people themselves would likely help engineers to imagine how their decisions could impact others and would thereby lead to better products. This is an area worthy of attention in engineering education to encourage engineering design practices that are ultimately kinder to the natural environment and those who depend on it.

Some other implications emerge from the work more broadly. For example, engineering education has traditionally focused on technical problems and their solutions, and topics of ethics have typically received little attention in most engineering classrooms and programs. Even in courses dedicated to engineering ethics, human values explicitly tied to care and concern for the well-being of others are seldom discussed, and the focus tends to be on more abstract issues of rights, duties, fairness, and utilitarian principles (e.g., the greatest good for the greatest number of people). This chapter has demonstrated the application of an ethical framework (care ethics) that deals specifically with care and concern for others. I view this as a missing dimension to engineering education broadly, and to engineering ethics education in particular. By demonstrating the value and applicability of care-ethical responsibility for exploring ethical practices in engineering, this work suggests new avenues for coursework and assignments that can expose students to additional considerations of the ethical impact of engineering work beyond those most commonly discussed (e.g., duties, rights, utility).

In the present work, unintended consequences of e-waste in industrializing regions were highlighted. Other topics that have humanitarian or social justice themes could also be explored through a care ethics lens (e.g., see Campbell, Yasuhara, and Wilson 2015). E-waste and other topics could be covered in courses dedicated to engineering ethics using a variety of ethical frameworks in addition to care ethics (i.e., a pluralistic approach). Alternatively, a care ethics framework could be introduced in programs that use an “ethics across the curriculum” approach to examine a variety of topics and contexts that would benefit from care-ethical considerations.

Humanitarian Engineering courses and programs can also benefit from this work because such programs are premised on the idea of engineers in a “care-giving” role helping others address their needs. Care ethics and the notion of Responsibility are important considerations to reflect upon when engaging in activities like those performed in service learning programs or by groups like Engineers Without Borders (EWB) and Engineers for a Sustainable World (ESW).

A practical way to use this work in any of the above-mentioned courses and programs is to create assessment rubrics based on care-ethical considerations. Such rubrics could be used formatively by students for self-assessment or peer-assessment, or by instructors for grading projects or evaluating student approaches to design. Based on the findings in this chapter, I suggest the following measures of care-ethical responsibility: (a) multiplicity and variety of indicated stakeholders (e.g., simple counts, variety of different stakeholders, or indications of direction of influence), (b) explicit consideration of disadvantaged stakeholders (e.g., those who are vulnerable, powerless, underprivileged), and (c) indications of appropriate, collaborative responsibility (e.g., that avoid the two extremes of over-committing and diffusing/deflecting responsibility).

4.5.3b. Implications for Empirical Educational Research

One idea for future work is to look for patterns across demographics. For example, one might hypothesize that women would bring a different set of considerations to the e-waste problem than men (e.g., see Kilgore et al. 2007b, 2007a), or that non-native speakers of English would understand and/or express responsibility in different ways (e.g., see Bao’s quote and the associated footnote 15 in Section 4.4.2), ways that would require additional research methods, such as interviews or focus groups, for meaningful analysis.

Another potential topic of future work was identified in Section 4.4.2 with the ideas of agency and power to act, or in other words, what engineers think they are capable of and allowed by their profession or employers to do. As an aspect of care-ethical responsibility, an engineer’s sense of agency will influence the kinds of things they will attempt and the people and organizations with whom they will think to collaborate. In Sections 4.3.2 and 4.4.2, I looked at responsibility

assumption (i.e., who was thought to be responsible for the e-waste recycling problem). Future work might look at how or the ways in which engineers are said to enact their responsibility for the e-waste problem (i.e., what actions are suggested for engineers to take), or it might examine the ways engineers interact with others when assuming responsibility for the problem. Both of these ideas would support further exploration of responsibility assumption, agency, and awareness of power (and its limitations/constraints).

In terms of Tronto's framework, notions of interacting with others also feed forward to care-ethical competence in that neglecting to work with non-engineers in addressing such a complex problem as that of e-waste would surely doom any potential solutions to failure. Thus, the sequence of "who -> how -> ways of interacting" creates a bridge from care-ethical responsibility toward care-ethical competence, providing a predictive measure¹⁸ of the promise or likelihood of Competence. Future work might explore this bridge, as well as find ways to assess Competence directly by studying design artifacts, design processes, or even the extra-/co-curricular activities of engineering students once they become aware of a problem and decide to do something to address it. Finally, future work might involve designing research studies to explore care-ethical thinking more broadly, for example, by expanding coverage of Tronto's care-ethics framework to include the other elements, like Attentiveness, Responsiveness, and Integrity. The engineering community would likely benefit from a deeper understanding of each of these elements, both separately and holistically.

4.5.3c. Implications for Engineering Ethics

Understanding the ethical implications of this work requires some additional discussion of care ethics. In this sub-section I lay out some care-ethical terms and concepts that help us shed light on the implications of the work for engineering ethics.

¹⁸ Though such a predictive measure would be most appropriately used for formative educational purposes or research, rather than for summative evaluation.

One ethical implication I highlight is the need to raise awareness of the e-waste recycling problem. This was even pointed out by two participants, including Diego, who wrote “First and foremost is an engineer realizing that recycling of electronic waste affects everyone.” Using a language of care, we could say that the most salient needs in this scenario are those of human and environmental health in and around “backyard” e-waste recycling operations. We could also identify the “care-receivers” as the people and ecosystems near those facilities, and the “care-givers” as the modern engineers creating the electronic technologies that are eventually being recycled in harmful ways. Use of the word “care-giver” here may cause some readers to pause: in ordinary usage of the term, the work that care-givers perform usually requires direct interaction with care-receivers (such as in the doctor/patient relationship) but in the e-waste scenario, practical constraints of time and distance would prevent most electronics design engineers from ever interacting directly with the aforementioned care-receivers. Given the large proximal, temporal, and even causal distances between the two, it may be challenging to make the mental link between a circuit-board design engineer in an air-conditioned North American office and a villager ten years later in India extracting heavy metals using the family cooking pan.¹⁹

Nevertheless, for engineers to respond ethically as “care-givers” (i.e., by either addressing the aforementioned needs, or avoiding creating such needs in the first place) requires that they be aware of their involvement in this relationship, however distant it may be. Unfortunately, this relationship is nebulous for most engineers, as the problem is largely unknown and invisible to them. Greater awareness is needed both within technical contexts and without to reach more engineers, their managers and the companies they work for, as well as consumers and policy makers who need to be more aware of and responsible for the consequences of their decisions. As Pickren (2014) shows, institutions and NGO’s can serve to mediate the abilities of individuals and groups to ‘care at a distance’ and to make global connections more sustainable and ethical in the area of e-waste recycling and disposal.²⁰ Future work should explore such literature for effective

¹⁹ Unfortunately, this may be a common practice - see <http://ngm.nationalgeographic.com/2008/01/high-tech-trash/essick-photography> (retrieved March 23, 2016).

²⁰ Thanks to an anonymous journal manuscript reviewer for suggesting this connection to a related body of literature.

ways that engineers can improve the situation, and we as engineers, educators, and scholars should do what we can to help raise awareness of the problem in broader circles.

Another implication for ethics, one that involves rethinking the way engineering is practiced, emerges from a deeper understanding of care ethics. Tronto (1993, p. 114) pointed out that the way the duties of care are typically assigned in many western cultures has important implications. Her first two phases of care—“caring about” and “taking care of,” corresponding to Attentiveness and Responsibility, respectively—tend to be the duties of people with more prestige and power (e.g., doctors, policy makers, and administrators). Her last two phases of care—“care-giving” and “care-receiving,” corresponding to Competence and Responsiveness, respectively—tend to be the duties of people with less prestige and power (e.g., nurses, social workers, and janitors). This split in roles is often done in the service of efficiency: doctors examine patients and decide what to do, and then delegate to nurses, orderlies, and lab technicians so that the doctor can move on and use their expertise to help more patients. While the practical aspects of such delegations are perhaps difficult to contest, the quality and effectiveness of care can easily suffer in these situations, such as when communication within the care team is poor, or when the work is performed too quickly or without the necessary sensitivity to notice what is helping and what is not.

In the context of e-waste recycling, this imbalance of power holds true as well: it is the relatively powerful engineers of the industrialized world who are in positions to be primarily Attentive and Responsible. The forms of “care-giving” (Competence) they can perform are usually so far removed in time and distance that the Responsiveness phase becomes difficult if not impossible. This points to the importance of somehow closing the feedback loop so that the relatively powerful engineers can understand the importance of the needs they may be creating and assess whether or not their actions are having desirable outcomes. In other words, they must somehow improve the Integrity of their care by better aligning their Attentiveness, Responsibility, Competence, and Responsiveness with the needs of the people and ecosystems they are inadvertently impacting. The implication for engineering ethics suggested here is for engineers (as well as companies and even society) to rethink the roles and approaches to engineering that we currently employ. Is it ethical to continue the “business as usual” approach to electronics design now that we know some of the harm and damage it can cause?

Humanitarian engineering programs have the potential to improve this disconnect in the caring roles by taking more holistic and contextual approaches to engineering; however, the danger of paternalistic patterns of engagement are potentially high (see Vandersteen, Baillie, & Hall 2009; Campbell, Yasuhara, & Wilson 2015; and the idea of “less-than” in Schneider, Lucena, & Leydens 2009). Other approaches that involve changing the power relationships may also help, and engineering ethicists would be in good positions to suggest and advocate for alternatives. If nothing is done, we risk committing an ethical failing that Tronto terms “privileged irresponsibility” (1993, pp. 120-122, 146). Privileged irresponsibility is a “consequence of the unbalanced nature of caring roles and duties in our culture” by which the relatively privileged remain unaware of others’ difficulties that they do not themselves face. She gives the example of racism and “white skin privilege”²¹ in the United States. A similar problem seems to exist between industrialized and industrializing countries (and even within them) with regard to electronic devices and their eventual recycling and disposal: out of sight, out of mind. I believe the field of engineering ethics has a responsibility (care-ethical or otherwise) to help change the situation and create a more caring and socially just engineering profession.

4.6. CONCLUSIONS

In this chapter, I explored the concept of responsibility empirically using an ethical framework that is seldom applied in engineering contexts: ethics of care. Specifically, I grounded conceptual explorations of engineering responsibility in empirical findings from engineering student writing on the human health and environmental impacts of “backyard” electronic waste recycling/disposal in industrializing countries. The research was guided by the question of how students exhibit care-ethical responsibility in the context of “backyard” e-waste recycling and what the associated implications might be (e.g., on teaching and learning engineering and engineering ethics). My

²¹ White skin privilege is part of the implicit social system of racism that provides opportunities to some people, but not others, based on the color of their skin (Tronto 1993, p. 121). Unfortunately, those who benefit from this system need neither recognize their privilege, nor feel any responsibility for racism’s continued existence because they do not think they have a prejudice. Therefore, those in the dominant group, who have the most power to change the system, see no reason to do so. They need not even deliberately refuse to assume responsibility for the problem because they simply do not see it, and therefore, the difficulties experienced by minority groups persist.

analysis looked at essays from a purposefully diverse sample of engineering students in an introductory electrical engineering course in the western United States. Students were asked, among other things, to respond to the question of what modern engineers producing electronic technologies should do as an "ethical" response to the problem of "backyard" e-waste recycling. I performed two levels of analysis on these responses: the first was a descriptive coding that provided a foundation for the second, more interpretive layer.

In the first level of analysis, I looked at the stakeholders that students indicated and at whom they associated with responsibility for the e-waste recycling problem. In the second level of analysis, I adopted a framework for care ethics from the wider literature and used the empirical data to facilitate a preliminary, conceptual exploration of care-ethical responsibility within the context of engineering and the global e-waste recycling/disposal problem. Specifically, I examined three possible measures of care-ethical responsibility: (1) multiplicity/variety of indicated stakeholders, (2) consideration of disadvantaged (e.g., vulnerable, powerless, or underprivileged) stakeholders, and (3) manner of acknowledging engineers' responsibility. This exploration provided a first step toward understanding how care-ethical responsibility manifests in engineering, and was intended to seed dialogue within the engineering community about its responsibilities (care-ethical or otherwise) on the issue of global e-waste, with implications for engineering education and engineering ethics that suggest changes for educational policy and the practice of engineering.

Chapter 5. Ethical Responsibility in Engineering Students’ Design Considerations: Case Studies of Electric Power Systems for the “Developing World”

This chapter concludes the empirical exploration, examining the third of three humanitarian/social justice contexts: rural electrification in the “developing world.” It is comprised largely of a conference paper¹ accepted by the American Society for Engineering Education’s (ASEE) Ethics Division and present at the 2015 ASEE Annual Conference & Exposition. The final publication is available at ASEE’s Papers on Engineering Education Repository (PEER) via <http://dx.doi.org/10.18260/p.24024>. The chapter looks at the ways in which student teams approached preliminary designs for expanding a large-scale electric power system from an industrialized into non-industrialized region. Like the previous chapter, it adopts and develops the second of Tronto’s elements of care ethics, Responsibility, this time using a different methodological approach (a comparative case-study) and in different engineering context. It addresses the third part of the second research question (RQ2/RQ2-C) as well as a portion of the third research question (RQ3).

¹ Campbell, R. C., Yasuhara, K., & Wilson, D. (2015). Ethics in Engineering Students’ Design Considerations: Case Studies of Electric Power Systems for the “Developing World.” In *Proceedings of the American Society for Engineering Education (ASEE) Annual Conference* (pp. 1–18). Seattle, WA, USA: American Society for Engineering Education. <http://dx.doi.org/10.18260/p.24024>

5.1. INTRODUCTION

This work explores engineering ethics in a “developing world” context. There are many ethical frameworks with which to examine the involvement of engineers from industrialized countries in projects directed at the “developing world” (e.g., see the Ethics of International Engagement and Service-Learning Project 2011). The framework chosen for this study is *care ethics*, a.k.a., ethic(s) of care (e.g., see Tronto 1993, 2013, Held 2006, and Engster 2007). Care ethics is a normative ethical theory that emphasizes the importance of concern, responsibility, and context, rather than the impartiality and universal standards associated with the more common ethical notions of justice or duty. Compared to other, more conventional ethical theories, care ethics is particularly suitable for the “developing world” context because it helps draw attention to imbalances of power (e.g., inequality, differential opportunity, and limitations on autonomy) that are often neglected by other ethical frameworks (Tronto 1993).² This work contributes to the discourse of engineering ethics by exploring the application of an ethical framework from the wider literature that has not received much attention in engineering ethics. The present work extends the current literature by developing concrete, practical tools for exploring care ethics in the context of engineering, and applying these tools to better understand the care-ethical conceptions of future engineers.

5.1.1. DESCRIPTION OF THE DESIGN PROJECT

In this work, I present a comparative (cross-case) analysis of a selection of design project reports written by senior undergraduate engineering students at a large research university in the western United States. These students were all majoring in electrical engineering, specializing in electric power systems engineering. To complete these projects, groups of three students assumed roles on mock consultant teams to recommend design options that addressed a problem of electro-mechanical dynamic stability in a large-scale electric power transmission system. The three-week project was based on that created by Hines & Christie (2002), which included a realistic model of the western U.S. transmission system and explicitly incorporated technical design, economics,

² Note, however, that care ethics may only scratch the surface of some of these issues. Another framing that perhaps better highlights the importance of local sovereignty can be found in the literature on decolonizing methodologies (see Smith 2012).

environmental considerations, and societal/ethical considerations. For this research, however, the assignment was modified to situate the project in a “developing world” context in which the students worked with an NGO in a fictitious country (see Figure 10) that had recently re-unified after years of differential “development” (not unlike Germany in 1990 or perhaps Korea sometime in the future).³ The electro-mechanical stability problem itself only affected the population living in the industrialized western side of the country, but students were also asked to recommend options for extending the power system into the eastern region in a way that environmental, social, and ethical considerations were taken into account. Students were provided with background materials to enable them to better understand and account for the social and cultural differences in the non-industrialized eastern half of the country. The problem statement below ⁴ served as the core prompt, and responses to part (c) are the focus of this chapter:

- a) Reports should give a description of the transient stability analysis conducted on the included base case system data. This section should include an estimation of the transient stability limit from the present operating levels (given in the enclosed data file [...]). North to South TTC (Total Transfer Capacity) should be calculated by increasing the Northwest generation and reducing Canju generation by the same amount until the system is not transient stable. The difference between the Northwest generation and the Northwest load is the Northwest export and is considered the amount of transfer to Canju. The value of this transfer at which the system is barely stable is the transient stability limit. South to North TTC is similarly calculated.
- b) Reports should recommend a North to South allowed TTC plan, and a South to North TTC plan at the CNI (Canju-Northwest Intertie) for each year in the given planning period.
- c) Reports should recommend options for extending the system into the eastern region that illustrate how environmental, social, and ethical considerations were taken into account. Note that the population of the eastern region is about half that of the west (38M vs 76M) and the [western power] system serves approximately 71M people.**

³ Note that even in countries where a reunification situation does not exist, such a context can highlight issues of ethics and social justice that may be present between neighboring countries with wide differences in material well-being (e.g., between countries in Western & Eastern Europe, the U.S. & Mexico, or South Africa & Mozambique).

⁴ Problem statement adapted from Hines (2001).

to the needs and culture of their people. Like many indigenous peoples (such as the Native American and Hawaiian Island people), they treat nature as sacred. They are thus very interested in power system technology that is minimally disruptive to the environment. They have also learned that the approach to power system design employed by much of the developed world is in fact sub-optimal and quite inefficient, because when large-scale generation is far from load centers, there is no way to effectively utilize waste heat.”

5.2. METHODS⁶

This chapter continues to address the dissertation’s second research question (RQ2), which read: In terms of care ethics, how do students in traditional engineering programs respond to problems of humanitarian or social justice nature? Specifically, the following sub-question (RQ2-C) guided this work: How do students exhibit Responsibility in the context of rural electrification? At the end of this chapter, I also explore some of its associated implications (RQ3), e.g., on teaching and learning engineering, further educational research, and engineering ethics including suggestions for educational policy and the practice of engineering. In this chapter, I have chosen a specific element of care ethics (Responsibility) operationalized⁷ it, and applied it to a selection of the available data. These operationalizations, the analysis approach, and the process of case selection are described below.

5.2.1. OPERATIONALIZING CARE-ETHICAL RESPONSIBILITY

Language of Responsibility

The first operationalization of care-ethical responsibility I employ is to look at the language of responsibility, i.e., the ways in which responsibility might be discussed in the group reports. For example, some might use the term “responsibility”, others the term “obligation”, or they may

⁶ Note: this section on methods contains material not published in Campbell, Yasuhara, & Wilson (2015).

⁷ I use the term operationalize here somewhat loosely in that my purpose in operationalizing is not really to measure but to improve understanding of the concept of care-ethical responsibility. While measurement and/or assessment may also be possible, this is not the primary objective.

simply talk about what “should” (or “could”) be done. In the context of engineers helping others in a developing world scenario, all of these varying ways of discussing responsibility could have something to say about care-ethics. For example, variations in wording may be indicative of commitment levels or notions of agency.

Paternalism

The second operationalization of care-ethical responsibility I employ looks at the level of responsibility assumed. In Tronto’s work, paternalism is acknowledged as a potential problem (1993, p. 145 & 170) and has been associated with the notion of taking too much responsibility (1993, p. 132; 2013, p. 63). Thus, paternalism is essentially a symptom of imbalance in the assumption of Responsibility. Paternalism involves a care-giver assuming he/she knows what is best for the care-receiver and making decisions that circumvent their wishes for their own good. This may not seem like a problem in some situations, such as when keeping a toddler from running into the street. In fact, this assumption of power may be acceptable and even desirable when care-receivers (be they humans, animals, or other living things) are incapable of making their own decisions or lack the knowledge or education necessary to understand the consequences of their intended actions. However, the danger of paternalism is that it can rob other people of their rights, destroy their sense of independence, and create long-term patterns of dependency and privilege (for example, see the literature on colonialism and multiculturalism in education, such as Dei & Kempf, 2005, and Banks & McGee Banks 2003, respectively).

Stakeholder Awareness

The third and final operationalization of care-ethical responsibility I employ involves stakeholder considerations. For the purpose of this work, stakeholders are broadly defined as those entities that would influence or be affected by the eastern expansion of the power system. Note that the terms “influencing” and “affected by” are used intentionally to avoid confusion (e.g., “affecting” vs. “affected” would be harder to distinguish). When deciding what to do about a situation, assuming care-ethical responsibility well requires knowledge of one’s own strengths and abilities, as well as awareness of others who might be better positioned to assist. This helps ensure that decisions about anticipated actions are not naïve or unrealistic. From the perspective of

Tronto's first element of care ethics (Attentiveness), consideration of stakeholders who are *affected* by the situation (especially those who are vulnerable, powerless or otherwise underprivileged) can be thought to carry more weight than consideration of the *influencing* stakeholders, who are better positioned to take care of themselves. However, from the perspective of care-ethical responsibility, I suggest that considerations of the influencing stakeholders are more the focus, because assuming responsibility is an active process undertaken by people who choose to influence the situation. This is not to say that, when assuming care-ethical responsibility, one should set aside or forget about affected stakeholders. Indeed that would be contrary to the spirit of care ethics, which espouses an integrated and holistic approach, as Tronto's Integrity of Care reminds us (e.g., see Figure 2, above). As a first-order estimation of care-ethical responsibility, we could examine, for example, the number or breadth of influencing stakeholders considered.

5.2.2. ANALYSIS APPROACH

Using the above three lenses under an interpretive conceptual framework, I employed qualitative methods of case study analysis in this work. ATLAS.ti qualitative data analysis software was used to manage and mark up the reports, which enabled analysis to occur in the full context of the written reports (rather than excising parts to be examined out of context) and thereby minimized misinterpretation. My analysis focused on student responses to the issue of expansion into the non-industrialized eastern region of the country (see Section 5.1.1).

5.2.3. CASE SELECTION

The reports analyzed in this chapter were written by senior undergraduate students at a large research university in the western United States. All students were majoring in electrical engineering and specializing in electric power systems. Students formed self-selected groups of three to complete the design projects and write up the reports. A total of 36 students were enrolled in the course, including 7 women and 29 men. Other demographics, such as race/ethnicity, were not collected for this class because it was not clear at the time if student work would be used for research purposes. However, in the interest of fair and unbiased grading, the reports had been anonymized shortly after receipt. IRB permission was requested some time later for their use in

research. Consequently, analysis was performed without any knowledge of the gender breakdowns or other characteristics of the group members.

To aid in the selection of cases to analyze in detail, word counts were performed of both the entire reports and the selections of passages identified as being pertinent to eastern expansion (coded “east-side addressed”). As shown in Figure 11, the word counts reveal something of the varying degrees to which the student groups engaged in the eastern expansion aspect of the project, with some groups writing approximately 2,000 words on the topic and others writing only about 200 (see left axis and bar chart in Figure 11). Normalizing by total word count, this corresponded to a range of 38% to 7% of the non-numerical content of the reports (see right axis and line chart in Figure 11). The two cases chosen are referred to in this chapter as Rose and Lilac.⁸ These reports were selected for analysis because they (1) exhibited contrasting approaches to eastern expansion, (2) differed in the apparent importance they placed on eastern expansion as indicated by the absence or presence of eastern expansion in the executive summary, and (3) provided the most material of interest for analysis. The selection of these two cases also attempts to minimize the effect of the varying levels of engagement with the east-side expansion.

⁸ Code names, rather than numbers or letters are used in this work to avoid implying order or rank. The names used in this analysis were inspired by a convention in the electric power industry for identifying overhead electrical conductor types using code words such as plant and bird names instead of alpha-numerical codes. Thus, the student groups in this work were randomly assigned names, in this case the names of flowers from The Aluminum Association, Inc. (1999, p. 7).

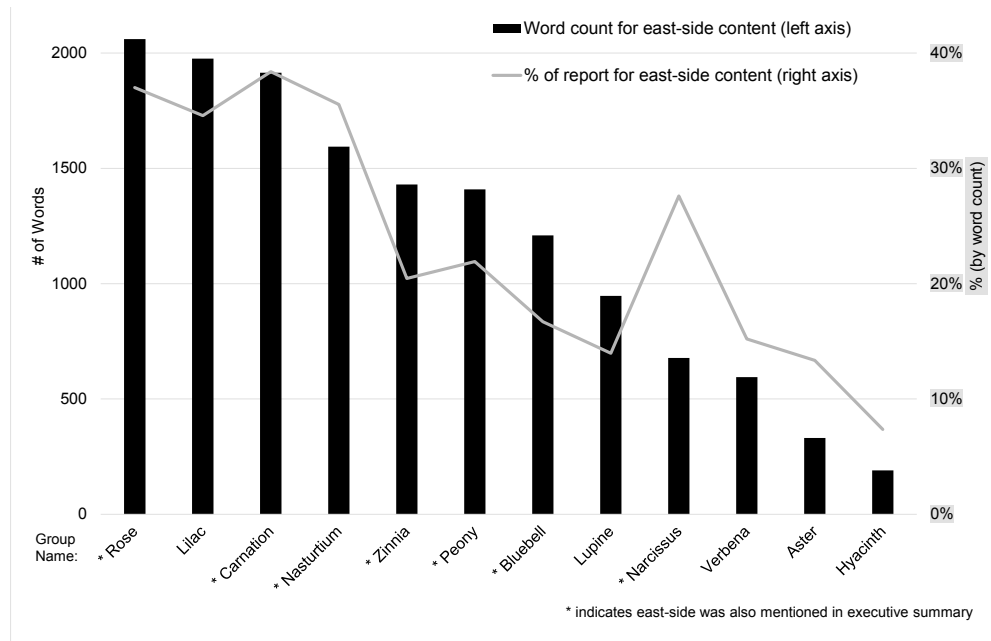


Figure 11. Word Counts Used to Identify Cases for Detailed Analysis

5.3. FINDINGS & DISCUSSION

In this section, I describe relevant selections from each of the reports with regard to care-ethical responsibility as operationalized in the Methods section. Due to variations in the way these concepts appeared in the two reports, the order of their presentation varies below. Quotations used from the reports are numbered for ease of reference. I conclude the section with a comparison of the findings between the two teams' reports.

5.3.1. TEAM ROSE

In this section, I present the findings from analysis of Team Rose's report, which contained over 2,000 words pertaining to the eastern expansion (37% of their total report). I begin with the language of responsibility, followed by indications of paternalistic/non-paternalistic approaches, and end with stakeholder awareness.

Language of Responsibility (Team Rose)

Team Rose wrote explicitly about responsibility in a number of senses, including that held by the western region toward the eastern region and that assumed by themselves as consultants. With regard to the latter, they espoused an active and explicit stance on group responsibility for their work in the eastern region when they wrote the following in the introduction of their report:

“We believe that it is our responsibility to provide guidance for a system in this region that preserves [the] traditions and culture of the area, but also bring[s] all the benefits of electrification, including improvements for health, education and wellbeing.” (1)

This quote demonstrates a clear and specific level of commitment “to provide guidance” and suggests a sense of agency in their ability to do so in a manner that is culturally sensitive and respectful. This quote will be further explored in the Paternalism subsection below.

Another sense of responsibility found in Team Rose’s report was that held by the western region toward the eastern region. About this they wrote,

“...providing support from the Western Region is socially responsible, as the Western region has a modern power infrastructure. The reunification necessitates that Western Gyumbi provide some of its significant resources to the Eastern side in order to help develop the country.” (2)

In terms of ethics, this invocation of social responsibility could be interpreted to focus on justice or duty rather than on care, but note that, as Engster (2007) suggested with the title of his book *The Heart of Justice*, the underlying motivation for fairness is essentially caring: if we did not care about others (and/or ourselves), then why would it matter if one group of people had resources that others did not, or had license to behave in ways that others did not? In fact, care ethics goes beyond the notion of equality presumed by common ethical notions of justice, fairness, or duty and draws attention to the fact that, in many cases, people are not and cannot be equal because they have different opportunities, privileges, and needs.⁹ While the above quote does evoke notions of

⁹ Note that Tronto associated these issues of difference/privilege with the Responsiveness element of care ethics, which seeks to address problems of vulnerability and inequality (Tronto 1993, p. 134), rather than with Responsibility. This shows the interconnected nature of care ethics and how multiple elements might overlap.

fairness and duty (e.g., that the western region should share its technology and resources with the eastern region because they are now a unified country), note the use of the phrase “to help,” which demonstrates a caring impulse that goes beyond fairness or duty. This phrase, in conjunction with the preceding phrase, “provide some of its significant resources,” shows recognition of the difference in opportunity enjoyed by the western region. These can be considered evidence of care-ethical responsibility.

Later in the report, Team Rose reiterated the idea of social responsibility with the following:

“The reunification of Gyumbi brings increased importance to the development of the Eastern Region’s electric infrastructure. As a single country, political leaders and policy makers have an obligation to build a power system on the east side that fully considers environmental, social and ethical factors.” (3)

Here they use the term “obligation” as held by specific stakeholders.¹⁰ While Tronto draws a distinction between obligation and responsibility (see the third paragraph of Section 2.2.1), common usage of the terms does not, and most dictionaries and thesauruses list responsibility as a synonym for obligation. Team Rose’s association here of obligation with considerations of social and environmental factors could be interpreted as evidence for awareness of the needs of others (human or otherwise), and thus as care-ethical attentiveness, which is a precursor to care-ethical responsibility.

Paternalism (Team Rose)

Quote (1) above, which focused on Team Rose’s responsibility as a consultant, provided an example of interacting with others in a non-paternalistic manner. In terms of care-ethical responsibility, this quotation demonstrated an approach to assuming responsibility that appeared sensitive to cultural differences and sought to avoid paternalistic decisions that could even destroy those differences. The phrase “provide guidance” suggested awareness of the role they were playing as advisors rather than designers for the eastern people. Similarly, the phrase “preserves traditions and culture” showed awareness of the significance of the way in which that guidance

¹⁰ This quote will be further explored in the Stakeholder Awareness sub-section below.

would be given. In fact, following quote (3) above (regarding the obligations of political leaders and policy makers), they wrote,

“Many of the traditions and culture of Eastern Gyumbi population are vastly different than citizens of Western Gyumbi. It is important that these lifestyles are preserved, along with providing much greater access to the benefits of electrification (i.e. increased healthcare and education).” (4)

These two quotations support the assertion that Team Rose was striving to avoid the danger of paternalism in their work. Also, while not the focus of this chapter, it is interesting to note that quote (4) demonstrates care-ethical attentiveness to the needs of the eastern people (i.e., preservation of their culture/lifestyle, as well as their healthcare and education).

Stakeholder Awareness (Team Rose)

A number of specific stakeholder groups were mentioned in the quotes above, several of which were indicated as influencing the situation. In quote (1), Team Rose indicated themselves, writing about their own role as technical advisers to provide guidance in a culturally sensitive manner. This demonstrated care-ethical responsibility in that awareness of one’s own role and how it is best performed are prerequisites for determining appropriate actions to take (or not to take).

Care-ethical responsibility can also be exhibited through awareness of other stakeholder groups. For example, in quote (2), Team Rose wrote about the western region (meaning its people and perhaps government collectively) and the positive influence it could have “to help develop the country.” In quote (3), they wrote of the obligation held by political leaders and policy makers to consider environmental, social, and ethical factors. This demonstrated awareness of the power and influence these stakeholders have to impact both people and the natural environment through the consequences of their decisions. The stakeholders indicated in both of these quotes are evidence of care-ethical responsibility in that they demonstrate knowledge of the roles and abilities of others, which helps ensure that anticipated actions are not naïve, unrealistic, or incompatible.

In quote (4), Team Rose mentioned the citizens of the western region; however, in this case it was not clear if they were invoked solely as a point of comparison with the differing cultures in

the eastern region, or if they comprised a potentially influencing stakeholder group. If the latter were the case, then the quote may suggest awareness of the danger of cultural imperialism, which could occur if the western region's culture (either by accident or intention) were to accompany expansion of its electric power system. This too then would show care-ethical responsibility through awareness of the potentially negative influence of this stakeholder group.

Systematic analysis of all stakeholders mentioned by Team Rose revealed a number of additional (and sometimes overlapping) stakeholder groups/entities. However, the only influencing stakeholders found were those mentioned above (i.e., political leaders, policy makers, the people/government of the western region, Team Rose themselves as consultants, and perhaps citizens of the western region). Regarding affected stakeholders mentioned, which would be considered indications of care-ethical attentiveness rather than responsibility, these included electric power customers, the farming and fishing industries, the economy, population centers, cities in the east side, residents of the east side, and residents of the entire country.

5.3.2. TEAM LILAC

In this section, I present the findings from analysis of Team Lilac's report, which contained over 1,900 words pertaining to the eastern expansion (35% of their total report). Due to the way the care-ethical considerations of interest intersect with the structure of the report, I begin this time with stakeholder awareness, followed by language of responsibility, and end with indications of paternalistic/non-paternalistic approaches.

Stakeholder Awareness (Team Lilac)

Systematic analysis of Team Lilac's report revealed awareness of several influencing stakeholders and many affected stakeholders. Most of these occurred in a section of the report labeled "Environmental Impacts." This section considered transmission line impacts and suggested mitigation strategies for a variety of potential issues, including those associated with aesthetics, agricultural lands, archeological/historical sites, endangered and protected species, property owners, recreation areas, waterways, wetlands, and woodlands. Undergraduate

engineering students would not normally be expected to possess such considerable knowledge of these various issues and the associated stakeholder groups, but in this case the students discovered a reference document published by a U.S. state public service commission specifically on the subject of the environmental impacts of transmission lines (see Public Service Commission of Wisconsin 2009), which clearly aided them in structuring and writing this section of their report.

Two influencing stakeholder groups that appeared in Team Lilac’s report were archeological and historical preservation societies/organizations. These were mentioned in association with responsibility (to be discussed further in the next subsection) for protecting sites with archeological/historical value. Another group that was discussed in terms of its influence was farmers who would work with others (presumably engineers who were not explicitly mentioned) on the placement of poles/towers to mitigate impacts on farm operations and/or agricultural lands. These two instances demonstrated care-ethical responsibility by showing knowledge of potentially overlooked stakeholder groups who might have a special role to play (i.e., providing the requisite knowledge and capability of identifying historically important areas in the first case and in optimizing farm operations in the second).

Another influencing stakeholder group that Team Lilac mentioned was the electric power utility who would be involved in compensating owners of private property for the use of their land. On this they wrote,

“If the path of the lines needs to cross private property, negotiations about fair payments need to be made between land owners and utilities to compensate for the negative impacts.” (5)

In this case, the relevance of this consideration to the eastern expansion scenario is questionable, given that the concept of private property may not even exist in the tribal lands. However, if we focus on the influencing stakeholder (rather than what appears to be a misidentified affected stakeholder)¹¹, this quote also shows care-ethical responsibility through awareness of the influence of the electric power utility and its obligation to fairly compensate affected stakeholders.

¹¹ Team Lilac explicitly indicated that the environmental impacts section of their report was intended for considerations of the Eastern expansion scenario. However, given the source of the information it contained and the industrialized audience for whom that source was originally written, this section of the report sometimes

Systematic analysis of all stakeholders mentioned by Team Lilac revealed a number of additional (and sometimes overlapping) stakeholder groups/entities. However, the only influencing stakeholders found were those mentioned above (i.e., archeological and historical preservation societies/organizations, electric power utilities, and farmers). It is perhaps noteworthy that this team did not explicitly indicate themselves as influencing stakeholders (more on this in the next section). Regarding affected stakeholders mentioned, which would be considered indications of care-ethical attentiveness rather than responsibility, these included owners of private property, users of recreation areas, farms/farmers (who were indicated in both directions of influence), endangered and protected species of plants/animals, and the plants/wildlife/ecosystems associated with waterways, wetlands and woodlands.

Language of Responsibility (Team Lilac)

Team Lilac explicitly referred to responsibility only once in their report. This occurred in connection with a suggestion to mitigate concerns over preserving locations of archeological or historical value. Specifically, they suggested finding

“...organizations or societies in that location that are responsible for protecting archeological and historical sites so that information can be found about whether a[n archeological] survey needs to be done at the construction site.” (6)

In this quote, responsibility was ascribed to others outside the engineering-consultant role of the group. (Note: Care-ethical considerations due to stakeholder awareness evinced in this quote were discussed in the previous section.)

appeared to better cover considerations of transmission line construction in the industrialized western region (i.e., since adding a supplemental transmission line was suggested as a solution to the stability problem of the western region). None-the-less, many of these stakeholder considerations could have been conceptually extended to consider native inhabitants and more culturally appropriate means of addressing their concerns. Unfortunately, Team Lilac did not make the effort to adapt these industrialized-world considerations to the context at hand. This idea will be further explored under the Paternalism section below.

Another way responsibility was discussed in Team Lilac's report was through use of the word "should" when discussing issues related to others' responsibilities, such as that of financial burden:

"The social and ethical issues that affect this extension project are the argument as to who should incur the construction cost." (7)

Here the phrase "who should incur" could easily be replaced with the phrase "who should be responsible for" and would suffer no change in meaning. Thus, responsibility is invoked in a conventional sense of duty or obligation. They then continue,

"The population of the eastern region is half that of the western and they are a less developed area so these people lack the capability to generate the revenue required to undertake the construction of the transmission lines. It would not be fair to raise rates in the western region in order to pay for an expansion project, which primarily benefits the Eastern Area." (8)

This quote clearly focuses on the issue of justice or fairness, and while the relative financial disadvantage of the eastern region is acknowledged, this does not appear to matter from the perspective of fairness. However, the following sentence appears more care-ethically oriented with this concession:

"From an ethical perspective, it would be wrong to leave 1/3 of the Gyumbi population without a reliable interconnected source of power so minor construction projects should be made in the future." (9)

The word "should" in the quote above serves as a proxy for responsibility without clearly identifying the responsible party. In this case, their use of the word is consistent with their role as consultants, and the responsible party is understood to be their client or perhaps the governmental agencies and other decision-makers with whom the report would likely be shared. Looking at the above three quotes together shows that this group conceives of ethics as something more than just justice or fairness and has perhaps an intuitive¹² sense that differences in power, opportunity, and privilege need to be somehow taken into account. Care ethics would have provided them a helpful

¹² A statement near the end of the report indicated that this group struggled with understanding the definition of social and ethical issues, tried to look online for information, but found nothing useful due to time constraints. Then they wrote: "As a result, common knowledge on what our interpretations was used to answer the question."

framework in this regard if it had been provided (see Section 5.4.2) or were more easily found in an Internet search targeting engineering ethics.

Finally, it is worth noting that Team Lilac made no explicit statements of their own group's responsibility for the eastern expansion. This could suggest a low level of commitment to assuming responsibility for this aspect of their work. In contrast, there were several explicit indications of Team Lilac as an influencing stakeholder in the solution to the western region's stability problem. An alternative explanation for this difference (beyond, or in addition to, a low level of commitment to the eastern expansion portion of the project) might be variations in writing style, as it is possible that different team members wrote each these sections. Nevertheless, there are indications of implicit assumption of responsibility for their role as consultants in the eastern expansion. These appeared in the report as preliminary design options they explored for expansion into the eastern region¹³ and as mitigation strategies they suggested to address potential concerns over constructing new power transmission infrastructure (see the Stakeholder Awareness section above).

Paternalism (Team Lilac)

As suggested in a footnote of the Stakeholder Awareness section for Team Lilac above, some of their suggestions for mitigation strategies appeared lacking in care-ethical responsibility due to a lack of cultural sensitivity. This can easily lead to paternalism, through which the engineer assumes too much responsibility and usurps the freedom of those they are attempting to help. While many of Team Lilac's stakeholder considerations could be conceptually extended to consider native inhabitants and more culturally appropriate means of addressing their concerns, they did not make the effort to adapt many of their industrialized-world considerations to the context at hand. Quote (5) above was an example of this, given that the concept of private property may not even exist in the non-industrialized tribal lands. Another example was the suggestion to mitigate concerns over visual aesthetics using

¹³ Team Lilac provided line drawings indicating (1) a loop/ring system connecting all the eastern cities with the two nearest western generation sites and (2) a radial system extending from the nearest western generation site to each eastern city via separate laterals off the main line.

“...vegetation such as trees or bushes [that] could be used to block the view of the lines and poles so that they become less intrusive.” (10)

This suggestion seems to miss the point that the people in the eastern region view nature as sacred. Simply hiding the environmental damage caused by clearing a transmission line’s right-of-way fails to address the core problem of harming nature in the first place and could show disregard for the beliefs of the people. Such an approach to technological and economic development would be paternalistic (i.e., too much responsibility being assumed by the engineers, ostensibly for the good of the people). Evidence of paternalistic thinking was even articulated by Team Lilac in the following quote, which directly followed quote (9):

“Even though the indigenous people in the eastern region view modernization as an invasion into Mother Nature, improving power transmission [in] that area aids in future development & prosperity of the Eastern region.” (11)

This quote seems to suggest that a modern electric power system like that of the western region (and that of most industrialized nations today) should eventually be forced on the eastern region to ensure development and prosperity in spite of the religious beliefs of the indigenous eastern people. Apparently, Team Lilac did not explicitly consider alternative approaches to electrification (some of which were even suggested in the project materials) that could be possible under the social/environmental constraints given for the eastern region. Perhaps needs for cultural variation and local sovereignty were trumped by learned tendencies or values in technical design that favor universal rather than local, contextual solutions.

5.3.3. CROSS-CASE COMPARISONS

As a first-order estimation of the relative levels of care-ethical responsibility exhibited in these reports, we could compare the number and breadth of relevant stakeholders considered. Limiting the analysis to clear indications of both stakeholders and their influence, we see that Team Rose considered five stakeholder groups (i.e., political leaders, policy makers, the people via the government of the western region, and Team Rose themselves as consultants). For Team Lilac, there were four (i.e., archeological and historical preservation societies/organizations, electric power utilities, and farmers). However, the difference in these numbers is not significant,

especially given that additional stakeholder groups/entities were implied in both reports. Rather than expanding the analysis to include implied stakeholders (which could involve more challenging and subjective interpretations), I chose instead to look at the breadth of these explicitly mentioned influencing stakeholders. Here we see that Team Rose mentioned more key, primary stakeholders (e.g., themselves, political leaders, policy makers), while Team Lilac included more secondary or peripheral stakeholders (e.g., farmers, archeological and historical preservation societies/organizations). In terms of responsibility (care-ethical or otherwise), it is clearly important to fully consider the key, primary stakeholders, as without them the actions of the secondary stakeholders may be insignificant. Team Rose thus had the more care-ethically responsible considerations in this regard.¹⁴

Another way to compare levels of care-ethical responsibility in these reports is to look at the language of responsibility. Unlike Team Rose, who wrote explicitly of assuming responsibility for the eastern expansion aspect of the project, Team Lilac made no explicit indications in this regard. Clearly an articulated, self-aware approach like that of Team Rose is preferable to, and more likely to yield good results, than the implicit (and possibly unexamined/unconscious) approach of Team Lilac. Additionally, Team Rose's report espoused a much lower level of paternalism than that of Team Lilac. While there is much to learn from both reports, Team Rose's was more care-ethically responsible across all three measures.

5.4. CONCLUSIONS

In this chapter, I applied care ethics to a selection of project reports written by electrical engineering students in a senior capstone design course at a large research university in the western United States. The three-week project involved recommending design improvements to an existing large-scale electric power transmission system and explicitly incorporated technical design, economics, and consideration of environmental, societal, and ethical issues. The project was

¹⁴ In terms of care-ethical attentiveness, however, Team Lilac's list of affected stakeholders is clearly the stronger of the two (see the last sentence of each group's Stakeholder Awareness sections above).

contextualized in a “developing world” setting and highlighted issues of ethics and social justice that are present between neighboring counties with wide differences in material well-being.

In this chapter, I focused on a single element of Tronto’s (1993) care ethics framework: responsibility. I then proposed three operationalizations of this element and used them as lenses for case study analyses of the reports from two student groups. While case studies are not intended to imply prevalence of findings or lead to widely generalizable conclusions, they can uncover things that might otherwise remain hidden and suggest questions for further inquiry. The case study approach provided the opportunity to examine the data in more depth and supported development at the conceptual level that would be considerably more difficult (if not impossible) using other methods. This proved to be a useful means of bridging between the empirical and conceptual aspects of the work, which, while presented in the standard IMRD (Introduction, Methods, Results, Conclusions) order, were actually co-developed iteratively, with the ideas in the methods section both constraining and being modified by the findings over the course of analysis and chapter development.

The findings showed differences in the way responsibility was discussed, which may be indicative of varying levels of commitment and/or notions of agency. Further exploration, such as explaining why these differences exist and what they might mean, is suggested as future work. I also found contrasting approaches to design in the developing world context, with one group demonstrating awareness, sensitivity, and appreciation of the expressed needs of the end user, and the other group adopting a more paternalistic approach suggestive of technological imperialism.

5.4.1. LIMITATIONS OF THE STUDY¹⁵

I should point out that as the course instructor, I met regularly with the class as a whole and also met periodically with each of the student groups. Consequently, I found that some groups enthusiastically embraced the developing-world context, while others tried to ignore or minimize it as much as possible. The low sample size combined with the high variability in engagement is

¹⁵ Note: this section on limitations was not published in Campbell, Yasuhara, & Wilson (2015).

an interesting finding in and of itself, though not one I chose to highlight in this chapter. These different levels of engagement should perhaps be considered when interpreting the findings. In selecting these two case studies, I have tried to minimize the effects of differential engagement by selecting the two reports that were the most prolific in terms of the content of interest; however, I acknowledge the possibility that the difference in the way these groups approached the task could be due to differences in engagement. This does not, I think, devalue the findings, but simply suggests a need for future work to uncover reasons why some students may be resistant to contexts of a humanitarian or social justice nature.

5.4.2. IMPLICATIONS FOR EDUCATORS AND RESEARCHERS

One possible implication of this work stems directly from the findings and is directed at the engineering curriculum. If the paternalistic approach to design exhibited by Team Lilac above proves to be common (and preliminary analysis of remaining data from this course indicates that other groups used similar approaches), then this suggests that concepts of design that are user-centered and participatory (e.g., see participatory design in Appendix B.3) should be formally introduced in more disciplines, as they are largely unknown in power systems engineering and electrical engineering, as well as other branches of engineering that have historically focused on the design of large-scale infrastructure (e.g., civil engineering). Participatory practices should occur early and consistently in the design process to maximize their effect. Also, waiting until a senior design project to introduce engineering students to what some people might consider an ethical responsibility to design for the user is clearly not ideal; such considerations should occur much earlier in the curriculum.¹⁶

Some implications emerge at the intersection of analysis, method, and conceptual framework as developed in the work. For example, note that the development of the operationalizations of care-ethical responsibility used in this work and their application to the analysis of these student reports was performed several years after the reports themselves were written. Thus, there was no opportunity to provide feedback to those students on the care-ethical strengths and opportunities

¹⁶ Many thanks to the anonymous conference paper abstract reviewer who suggested this.

for improvement of their work. However, the ideas and lenses presented here can be used by other educators (and will be used by the authors) in future courses to inform the design of course materials, exercises, and evaluation/grading criteria. For example, students could be asked to perform assessments of their own work or that of their peers to examine the language of responsibility or the ways in which responsibility was discussed (e.g., implicitly vs. explicitly, or as compulsory/obligatory vs. voluntary/aspirational). They could also identify numbers and types of stakeholders considered and whether or not these stakeholders show care-ethical responsibility (e.g., reflective self-awareness of the engineer's own role, and other important stakeholders who should be called on for their abilities and expertise) or care-ethical attentiveness (e.g., awareness of vulnerable stakeholders who are affected by the situation). Similarly, students could self- or peer-assess for presence (or levels) of paternalism.

The operationalizations and findings from this work can be used to inform future research, such as the development of interview questions and/or survey items designed to capture engineering student responses to issues of humanitarian or social justice nature. Only through the appropriate use of larger sample sizes and validated, reliable instruments can questions of cause and effect be answered and generalizable conclusions be reached. This work provides some of the necessary first steps toward understanding the concepts and constructs needed to begin larger-scale investigations into this area of research. In terms of conceptual/philosophical research, this work similarly provides some first steps, empirically grounded in an engineering context, from which to explore how care ethics might be applied to engineering or how engineering might need to change to become more consistent with care ethics.

Chapter 6. Summary and Conclusions

In this chapter, I summarize the key findings and implications from each of the core chapters of the dissertation (i.e., Chapters 2, 3, 4, and 5), synthesize across the chapters with respect to the chosen care ethics framework, and then provide concluding remarks.

6.1. SUMMARIES OF THE CORE CHAPTERS

6.1.1. SUMMARY OF CHAPTER 2

Chapter 2 addressed the question (RQ1) “How might care ethics manifest in engineering?” The primary contributions of Chapter 2 were conceptual and included applying a framework for care ethics from the wider literature to various engineering contexts, especially that of humanitarian engineering—the philanthropic use of engineering skills and services for community service, disaster recovery, or international development. The framework I adopted, that of political scientist J. Tronto (1993), facilitates understanding care ethics both analytically through comprehension of each of its constituent elements, and synthetically through the integration of those elements and the inter-relationships between them (see Figure 2). These features make it more accessible to an engineering audience than other formulations of care ethics in the literature, which I found to be less structured. Tronto’s framework describes care ethics in terms of four inter-related elements: Attentiveness, Responsibility, Competence, and Responsiveness, plus a fifth meta-level element, Integrity, which integrates the other elements into a cohesive whole (see Section 2.2.1 for more on this framework). Another contribution from Chapter 2 was a means of avoiding the problem of paternalism inherent in most ostensibly caring endeavors (e.g., humanitarian engineering) through adopting a mindset of equality, humility, and respect when interacting with those one seeks to help (see Section 2.4.2).

6.1.2. SUMMARIES OF CHAPTERS 3, 4, AND 5

Chapters 3, 4 and 5 involved analyses of empirical data, guided by the following overarching research question (RQ2) “In terms of care ethics, how do students in traditional engineering

programs respond to problems of humanitarian or social justice nature?” These analyses, when combined with the additional conceptual development necessary to operationalize care ethics and understand it more deeply in specific contexts, resulted in both empirical and conceptual outcomes. These outcomes were based on engineering student perspectives in three different engineering contexts, each involving problems of a humanitarian and/or social justice nature in which caring qualities could reasonably be expected to be important. Note that some implications of the work in these chapters stem directly from the findings, and some are associated at a higher level with the intersection of analysis, method, and conceptual framework as developed in the work.

Given the relatively small sizes of the samples and the interpretive nature of the work, any generalizations in the sub-sections below are best viewed as *moderatum* generalizations (Williams 2000; Payne and Williams 2005), in which both the scope of the claims and the degree to which they are held are appropriately moderate. Because these chapters use empirical findings to scaffold conceptual exploration, the nature of *moderatum* generalizations that can be reasonably drawn will also vary.¹

6.1.2a. Summary of Chapter 3: Hurricane Katrina & Care-ethical Attentiveness

Chapter 3 explored the first element of care ethics—Attentiveness—in the context of natural disaster prevention. Specifically, it looked at the ways in which students in 2006 said their knowledge of Hurricane Katrina (and its impact on New Orleans) influenced their design thinking on a river retaining wall design task. This exploration began with an inductive, descriptive coding of if/whether knowledge of the disaster influenced student thinking, and if so, how. This was then followed by an explicitly interpretive layer of analysis that looked at the ways in which Katrina knowledge influenced design thinking through a lens of care-ethical attentiveness operationalized as implicit/explicit considerations of others and/or needs. The findings were then discussed in terms of both layers of the analysis and possible implications of the work were considered.

¹ Note: this paragraph on moderatum generalization is from Campbell & Wilson (2016).

In Chapter 3, I found that most of the students (nearly three fifths of the sample of 73) reported that their knowledge of the disaster indeed affected their design task responses in some way; however, many (over a third) indicated that it did not (see Table 5). These findings have implications for learning transfer (see Section 3.6.1a), and suggest that simply invoking pre-existing knowledge of well-known humanitarian issues, like those caused by Hurricane Katrina, could help engineers think beyond the narrow confines of purely technical considerations during design. This will likely happen spontaneously for many students, but for all to benefit, explicit prompts may be needed to help students connect their knowledge of the issues to the task at hand. Leveraging these kinds of opportunities could be an easy way to encourage broader, more care-ethically attentive design thinking.

I also found that, when it was a factor, knowledge of the disaster caused students to consider issues related to four categories or areas of concern: People/Society, the Natural Environment, the Designed Artifact, and Aspects of Design Approaches (see Table 6). Furthermore, knowledge of the disaster caused most students (nearly three fifths of the 36 who gave unambiguous ways in which it did so) to consider issues related to more than one of these areas of concern; however, many students (over two fifths) only indicated issues related to one (see Figure 4). While these findings are interesting from the perspective of teaching, learning, and better understanding design (see Section 3.4.2), I will focus here on the care-ethical interpretations.

In brief, I found that Attentiveness was present and reflected to varying degrees in the quotes comprising all four categories above. The value of these quotations and interpretations are difficult to show meaningfully in a concluding paragraph (the meaning is in the details), thus, I refer the reader to the respective sub-headings of Section 3.4.2. Briefly, the People/Society category revealed the most explicit awareness of others and their needs. The Natural Environment category was difficult to interpret for several reasons (see Section 3.4.2). The Designed Artifact and Aspects of Design categories revealed limited degrees of care-ethical attentiveness, which is not surprising given the narrow focus and brevity of the design task prompt and the relatively simple stakeholder operationalization employed. Indeed, what is rather surprising is that knowledge of the hurricane triggered so many considerations other than those focused directly on the design artifact. This highlights the value of the context that Hurricane Katrina provided: taking what would otherwise

appear to be mundane and routine wall-centric design considerations and transforming them into salient concerns that are all the more compelling because they vividly remind the designer to be more Attentive and aware of the reasons behind performing such design work in the first place.

As detailed in Section 3.6, the work has outcomes that are of interest to educators and educational researchers, including suggestions of possible directions for future work. For example, implications of the work relate to learning transfer, as described above. Also, the study's emergent high-level categories can also be used as a framework to aid in teaching and learning about the complexities of design (see Figure 7). Other outcomes of the work include making care-ethical attentiveness more concrete (see the stakeholder operationalization of Attentiveness in Section 3.2.1b) for use both by other researchers and for educational assessment (e.g., formatively for self- and/or peer-review).

6.1.2b. Summary of Chapter 4: Electronic Waste & Care-ethical Responsibility²

Chapter 4 explored the second element of care ethics—Responsibility—in the context of “backyard” e-waste recycling. Specifically, it grounded conceptual explorations of engineering responsibility in empirical findings from engineering student writing on the human health and environmental impacts of “backyard” electronic waste recycling/disposal in industrializing countries. This work was guided by the question of how students exhibit care-ethical responsibility in the context of “backyard” e-waste recycling (RQ2-B) and what the associated implications might be (e.g., on teaching and learning engineering and engineering ethics) (RQ3). The analysis looked at essays from a purposefully diverse sample of engineering students in an introductory electrical engineering course in the western United States. Students were asked, among other things, to respond to the question of what modern engineers producing electronic technologies should do as an “ethical” response to the problem of “backyard” e-waste recycling.

Two levels of analysis were then performed on these responses: the first was a descriptive coding that provided a foundation for the second, more interpretive layer. In the first level of

² This section contains material adapted from Campbell & Wilson (2016).

analysis, I looked at the stakeholders students indicated and at whom they associated with responsibility for the e-waste recycling problem. In the second level of analysis, I used the empirical data to facilitate a preliminary, conceptual exploration of care-ethical responsibility within the context of engineering and the global e-waste recycling/disposal problem.

The coding results indicated that nearly all students considered stakeholder groups that I categorized as technical/economic, environmental, and citizenry, but only about half the students mentioned governmental or non-governmental organizations (Table 9). These data suggests a need to raise student awareness about how engineers might work with governments and NGOs in addressing the problem. Comparing the data against an authoritative stakeholder list used as a benchmark (Table 11) shows that several key stakeholder groups involved in addressing the e-waste problem were missed by most students (Table 12 and Figure 9). Most notably, Refurbishers (e.g., repair shops and service centers) were not mentioned and the idea of repair appeared in the writing of only one student. This is somewhat surprising given the ubiquity of electronic products in the U.S. that are easier to replace than repair (thus generating more e-waste), and given that product reparability is so obviously impacted by engineering design. This suggest a need to raise awareness about many of the downstream stakeholders and processes that handle electronic devices as they reach the end of their useful lifetimes so that engineers consider how their decisions could impact others. This is an area worthy of attention in engineering education to encourage engineering design practices that are ultimately kinder to the natural environment and those who depend on it.

Looking at these findings through a care-ethics lens (Section 4.4.1), I identified two possible measures of care-ethical responsibility as indications of the relative quality of responses: multiplicity/variety of indicated stakeholders, and consideration of disadvantaged stakeholders and their needs. Multiplicity/variety of stakeholders is an aspect of care-ethical responsibility that provides ties back to Attentiveness in Tronto's framework and increases the chances that disadvantaged (e.g., vulnerable, powerless, and/or underprivileged) stakeholders will have their voices heard and their needs met.

Coding also revealed that most (though not all) of these engineers of tomorrow associated engineers with responsibility for the e-waste problem in some way (Table 13). Furthermore, in spite of being asked specifically about the engineer's responsibility for the e-waste recycling problem, many participants associated other entities and/or stakeholders with at least some of that responsibility. Looking at these findings through a care-ethics lens (Section 4.4.2), I identified a third possible measure of care-ethical responsibility: manner of acknowledging responsibility. Here I examined variations in the ways in which students acknowledged engineers' responsibility and categorized them as (Table 14): (a) acknowledging (possibly sole and complete) responsibility for the problem, (b) sharing responsibility with other stakeholders, and (c) acknowledging limited responsibility for the problem.

In addition to the value of this work for informing engineering education and future empirical educational research (see Section 4.5.3), broader implications include identifying the ethical responsibility of engineers to improve their own awareness of the roles they may unwittingly play in the e-waste problem, and to raise awareness of the e-waste recycling problem. Another implication even involves rethinking the way engineering is practiced: perhaps engineers (as well as companies and even society) need to reconsider the roles and approaches to engineering that we currently employ. Is it ethical to continue a “business as usual” approach to electronics design now that we know some of the harm and damage it can cause to both our fellow humans and the ecosystem upon which we all depend?

6.1.2c. Summary of Chapter 5: Electric Power Engineering & Care-ethical Responsibility³

Chapter 5 also explored the second element of care ethics—Responsibility—in the context of rural electrification, but did so this time using a comparative case-study approach. While case studies are not intended to imply prevalence of findings or lead to widely generalizable conclusions, they can uncover things that might otherwise remain hidden and suggest questions for further inquiry. The case study approach provided the opportunity to examine the data in more

³ This section contains material adapted from Campbell, Yasuhara, & Wilson (2015).

depth and it better supported development at the conceptual level that I found considerably more difficult using other methods. This proved to be a useful means of bridging between the empirical and conceptual aspects of the work, which, while presented in the standard IMRaD (Introduction, Methods, Results, and Conclusions) order, were actually co-developed iteratively, with the ideas in the methods section both constraining and being modified by the findings over the course of analysis and chapter development.

In this chapter, I examined project reports written by groups of electrical engineering students in a senior capstone design course at a large research university in the western United States. The three-week project involved recommending design improvements to an existing large-scale electric power transmission system and explicitly incorporated technical design, economics, and consideration of environmental, societal, and ethical issues. The project was contextualized in a “developing world” setting and highlighted issues of ethics and social justice that are present between neighboring counties with wide differences in material well-being.

I developed three operationalizations of care-ethical responsibility in this chapter and used them as lenses to analyze the reports of two student groups. The first lens involved the language of responsibility, i.e., the ways in which responsibility was discussed in the reports. The second involved the notion of paternalism and looked at the level of responsibility assumed. The third involved stakeholder awareness/considerations looking specifically at those entities that would influence (rather than be affected by) the eastern expansion of the electric power system. The choice to focus on the “influencing stakeholders” was made because assuming Responsibility is an active process undertaken by people who choose to influence the situation (unlike Attentiveness, for which affected/disadvantaged stakeholders are more the focus).

The findings revealed differences in the way responsibility was discussed, which may be indicative of varying levels of commitment and/or notions of agency. Further exploration, such as explaining why these differences exist and what they might mean, is suggested as future work. I also found contrasting approaches to design in the developing world context, with one group demonstrating awareness, sensitivity, and appreciation of the expressed needs of the end user, and the other group adopting a more paternalistic approach suggestive of technological imperialism.

In addition to the value of this work to inform future research, course design, and educational assessment (see Section 5.4.2), another possible implication of this work is directed more broadly at the engineering curriculum. If the paternalistic approach to design exhibited by one of the groups above proves to be common (and preliminary analysis of the other data from this course suggests that other groups used similar approaches), then this suggests a need to promote understanding of other ways of relating to other through mindsets of equality, humility, and respect (see the third of Gadamer’s “I-Thou” modes in Section 2.4.2 The Problem of Paternalism and How to Avoid It). This also suggests that concepts of design that are user-centered and participatory (see Appendix B.3) should be formally introduced in more disciplines, as they are largely unknown in power systems engineering and electrical engineering, as well as other branches of engineering that have historically focused on the design of large-scale infrastructure (e.g., civil engineering). Participatory practices should occur early and consistently in the design process to maximize their effect. Also, waiting until a senior design project to introduce engineering students to what some people might consider an ethical responsibility to design for the user is clearly not ideal; such considerations should occur much earlier in the curriculum.

6.2. CARE-ETHICS SYNTHESIS

In Chapter 2, I adopted a care-ethics framework from the wider literature (Tronto 1993) and showed ways in which it might apply to engineering. I suggested in Section 2.4.1 (Ethics of Care as a Guiding Framework for Social Justice) that engineering as a field or profession appears to be taking up the early phases of care inasmuch as, after a history of serving primarily military, industrial, and/or commercial interests, engineers are becoming increasingly interested in more altruistic applications of their knowledge, skills, and abilities. In the language of care ethics, we could say they are now “caring about” or becoming more Attentive by recognizing the needs of a broader range of others. They are also increasingly motivated to “take care of” or assume Responsibility for helping others.⁴ I thus concentrated this dissertation on exploring the first two

⁴ Some individuals and groups, such as the Engineers Without Borders (EWB), are moving into the Competence or “care-giving” phase of care as they attempt to do something about the problems they see, and a few are even exploring the Responsiveness or “care-receiving” phase of care, as exemplified by EWB Canada’s Failure

elements of Tronto's framework in detail using empirical data to focus and facilitate conceptual exploration. In this section, I synthesize what I've learned about care ethics from across this work and show how it relates to all elements of Tronto's framework.

Attentiveness is the first element of Tronto's framework for care ethics and it is foundational since care in general is impossible without awareness of others and their needs. Furthermore, Tronto makes the claim that neglect of others and even ignorance of needs, be it willful or inadvertently habitual, can be considered moral failings (Tronto 1993, p. 127-129), especially given modern media and communication capabilities worldwide. With regard to other elements of Tronto's framework, good care-ethical attentiveness is a prerequisite for Responsibility (described below), because one must first be aware of a need before one can assume responsibility for addressing it. Additionally, the skills and abilities that enable Attentiveness (e.g., good communication, active listening) are also essential for the fourth element: Responsiveness (c.f. care receiving), which involves assessing the reaction of the care-receiver to the care provided and accounts for the problems of inequality and vulnerability that are present in any caring situation (Tronto 1993, p. 134).

In Chapter 3, I examined Attentiveness with regard to disaster prevention design in the context of Hurricane Katrina's aftermath. By operationalizing Attentiveness as demonstrated awareness of others (i.e., stakeholders other than engineers) and their needs (see Section 3.2.1b), I found Attentiveness reflected to varying degrees in student statements across all categories of responses. This work suggested that a humanitarian disaster context would help many students do design in a more care-ethically attentive manner by reminding them to explicitly consider issues related to people and/or the natural environment. The work also suggested that some students would likely not recognize the relevance of their knowledge of a humanitarian disaster, and adding such context would not improve their Attentiveness unless they were somehow prompted or reminded to do so.

Reports (e.g., see the 2015 Failure Report at <http://reports.ewb.ca/introducing-the-2015-failure-report/> retrieved March 31, 2016). However, as suggested in Section 2.3.4 Engineers as Philanthropists, significant numbers of engineers have only recently pursued philanthropy by striving, through their work, to care about those they perceive as less fortunate. Furthermore, as mentioned in Sections 2.2.2 and 4.1, care ethics has garnered little attention in the engineering-related literature to date. In this dissertation, I begin to fill the gap by taking a first step towards understanding how care ethics might guide or support such philanthropic endeavors in engineering.

Furthermore, the work suggested that even design decisions of a purely technical nature can be made with care-ethical attentiveness if they are appropriately motivated by considering the needs of (or potential impacts on) humans, society, and/or the natural environment.

Responsibility is the second element of Tronto's care ethics framework and is considered a central moral concept (Tronto 1993, p. 131): so central that it is the focus of her follow-up work (see Tronto 2013, p. 11). Once a need is identified, one must decide if one feels responsible for it and if so, how to respond. Care-ethical responsibility differs from other, more traditional notions of responsibility in several ways (see Section 4.1.1 for further details), including (1) its context dependence (i.e., consideration of both what should be done and what those involved are capable of doing); (2) its future orientation (i.e., focus on meeting needs rather than placing blame); (3) its consideration of disadvantaged stakeholders (e.g., those who are vulnerable, powerless, or underprivileged, and are thus affected by, but not easily able to influence the situation); (4) its voluntary, aspirational nature (i.e., one chooses to assume Responsibility rather than having someone else hold you responsible), and (5) its collective, democratic, and political nature (i.e., individual responsibility is not enough, we have collective responsibilities that must be approached in a participatory manner through dialogue and consultation).

In Chapters 4 and 5, I explored Responsibility by iteratively devising and applying a variety of measures. It is worth noting that all six indicators of care-ethical responsibility from these chapters (described below) tie directly to the next element of care ethics: Competence. This is because they are indicative of the promise, or likelihood of good "care-giving". In other words, assuming Responsibility can be viewed as a form of planning (i.e., "this is what I'm going to do, and this is how I'm going to do it"). Deficiencies in such planning, whether through neglecting to consider key influencing stakeholders or disadvantaged stakeholders, or through paternalistic approaches or placing inappropriate limitations on the scope of responsibility assumed, all these would lead to ineffective actions and unpromising solutions.

In Chapter 4, I began exploring Responsibility with regard to the problem of electronic waste in the context of the health and environmental impacts of "backyard" e-waste recycling in China and India. In this chapter, I operationalized Responsibility in three ways. First, I looked at

awareness of stakeholders broadly, including both those who influence and are affected by the situation. This served as a very coarse measure of how well Responsibility was being assumed inasmuch as the greater the number and/or variety of indicated stakeholders, the more likely that (a) planned actions would have the sophistication needed to positively impact the situation, and (b) disadvantaged stakeholders (i.e., those who are vulnerable, powerless, or underprivileged) would have their voices heard and their needs met.

Second, I looked more specifically at disadvantaged stakeholders, since assuming care-ethical responsibility well involves extra consideration of these stakeholders through appropriate focus on their needs and, in some cases, even privileging them over others. For example, who would openly deny that the health and livelihood needs of impoverished children should carry more weight than the financial profit needs of a consumer-electronic company's stock shareholders?⁵ Such considerations must play into any decisions made by those assuming Responsibility for the problems caused by "backyard" e-waste recycling. Thus, awareness of disadvantaged stakeholders further increases the likelihood that planned actions would be realistic and sophisticated enough to positively impact the situation.⁶ In terms of other elements of care ethics, awareness of disadvantaged stakeholders has obvious ties back to Attentiveness, and (as described in the previous sub-section) has ties to the fourth element of care ethics, Responsiveness. This illustrates the interconnected nature of care ethics and how multiple elements might intersect or overlap (see Section 2.2.1).

Third, I looked at who students associated with responsibility for the e-waste problem (i.e., engineers or non-engineers) and the manner in which responsibility was expressed (i.e., as manifest by limitations on engineers' responsibility and/or the sharing of responsibility with others). Given that these were engineering students who were likely aspiring to be engineers, their statements about the responsibilities of engineers were therefore likely to reflect thinking about their own personal and professional values, rather than being statements that ascribe

⁵ The fact that financial profits often trump the health and livelihood needs of distant others highlights the disconnect between our actions and our professed values, thereby showing the need for care ethics and the perspectives it can bring.

⁶ Note that this point not articulated explicitly in Chapter 4 for awareness of disadvantaged stakeholders.

responsibilities to others. This work revealed varying degrees of Responsibility in student writing as estimated by the above measures. It also suggested a need to raise awareness not only of the e-waste recycling problem itself, but of engineering student awareness of the potential roles of governmental and non-governmental organizations (NGOs), especially for finding ways that engineers can work with them to impact the e-waste recycling problem in a care-ethically responsible manner.

In Chapter 5, I also examined Responsibility, this time with regard to electric power systems design in the context of “developing world” rural electrification. Here, I used a comparative case-study approach and developed three new operationalizations of Responsibility. One involved a refinement of stakeholder considerations. I have found the language and ideas of stakeholder theory to provide a useful bridge between the soft, intuitive, emotion-laden nature of care and the hard, analytical, impersonal approaches and expectations in engineering.⁷ In Chapter 5, I looked specifically at stakeholder groups/entities that would influence, rather than be affected by, the situation. This nuance is insightful because it recognizes that assuming Responsibility is an active process undertaken by people who choose to influence the situation, and this distinguishes it from the comparable stakeholder-based measures used in the previous chapters. Specifically, recall that the stakeholder-based measure for Attentiveness in Chapter 3 focused on awareness of needs and others (non-engineering stakeholders) without attempting to distinguish the direction of influence.⁸ Similarly, one of the stakeholder-based measures for Responsibility in Chapter 4 focused on multiplicity/variety of stakeholders considered but went only so far as to claim that considering both directions of influence would be better than considering only one (see Section 4.4.1a). Finally, note that my use of disadvantaged stakeholder awareness as a measure of Responsibility in Chapter 4 (see Section 4.4.1b) focused on the affected, rather than the influencing stakeholders.

Another operationalization in Chapter 5 involved examining the ways in which notions of responsibility appeared in student design project reports. I found that their language of

⁷ I should also point out that researchers in the field of business ethics have observed and discussed the close alignment between stakeholder theory and care ethics – see Burton and Dunn (1996); Engster (2011); Palmer and Stoll (2011).

⁸ Although, direction of influence was used as a rhetorical strategy for presenting the findings in Section 3.3.2b.

responsibility, such as explicit use of terms like “responsibility” or “obligation” versus implicit indications of what “should” or “could” be done, permitted interpretations of levels of commitment and notions of agency. Recall that similar outcomes had also emerged from the Chapter 4 lens characterizing the ways in which engineers’ responsibility was acknowledged (see the last two sub-headings in Section 4.4.2). However, in Chapter 5, notions of agency only appeared clearly in one project report and were considerably more positive from a care ethics standpoint than those that appeared in several of the essay responses of Chapter 4. This confirms the assertion in Chapter 4 that there is a range of perspectives and reasoning with regard to notions of agency (see the last paragraph of Section 4.4.2), and further study would be needed to characterize and understand them.

The last operationalization of Responsibility to review from Chapter 5 involved the notion of paternalism by looking at the levels of responsibility assumed. Recall from Section 5.2.1 that paternalism is a symptom of imbalance in Responsibility assumption in which well-meaning caregivers assume they know what is best and make decisions that circumvent others rights and wishes, potentially even creating long-term patterns of dependency and privilege. In Section 2.4.2, I drew attention to the danger of paternalism in humanitarian engineering endeavors and suggested a means to combat it using mindsets of equality, humility, and respect. It is only by creating relationships using such mindsets that effective actions can be taken because only then will the necessary levels of Attentiveness and Responsiveness be possible to guide the assumption of Responsibility and the work of Competence. In brief, we could say that these mindsets create the necessary conditions for the Integrity element of Tronto’s framework.

6.3. CONCLUSIONS⁹

The National Academy of Engineering envisions “a future where engineers are prepared ... to ethically assist the world in creating a balance in the standard of living for developing and developed countries alike” and notes the importance of educating engineers who are “ethically grounded” (NAE 2004). Similarly, ABET (and other engineering accreditation programs around

⁹ This section contains material adapted from Campbell & Wilson (2016).

the globe) call for students to understand their professional and ethical responsibilities as well as the impact of engineering solutions in global, economic, environmental, and societal contexts.¹⁰ The work in this dissertation directly supports these goals by contributing to the definition of engineering ethics.

Building on a framework for care ethics proposed by political scientist J. Tronto (1993), I extended the ways in which care ethics has thus far been applied in the engineering literature, i.e., beyond mapping to design and problem-solving methodologies (Pantazidou & Nair, 1999), as a “standard of care” (Kardon, 2005), and as a conceptual framework for value-sensitive design (Van Wynsberghe 2013). Other researchers have recently explored the related concept of empathy in engineering (Walther et al. 2012; Hess, Fila, & Purzer 2016; Fila et al. 2016), sometimes along with the notion of caring (Strobel et al. 2011, 2013; Hess et al. 2012); however, my work complements this literature by focusing on the ethics of care as a normative, philosophical concept, and further develops it in specific engineering contexts of a humanitarian or social justice nature. My work also contributes to the literature preliminary insights into undergraduate engineering students’ proclivities for care-ethical thinking.

As such, this work provides some of the necessary first steps toward understanding the concepts and constructs needed to begin larger-scale investigations into this area of ethics research. The operationalizations and findings from this work can be used to inform future research, such as the development of interview questions and/or survey items designed to capture engineering student responses to issues of humanitarian or social justice nature, or in support of design-based research (DBR) initiatives that seek to bridge the gap between educational research and practice (see Brown 1992; Cobb et al. 2003; Design-Based Research Collective 2003). In terms of conceptual/philosophical research, this work similarly provides some first steps, empirically grounded in an engineering context, from which to explore how care ethics might be applied to engineering or how engineering might need to change to become more open to and consistent with the ideals of care ethics.

¹⁰ ABET Criteria for Accrediting Engineering Programs, 2015-2016, General Criteria 3. Student Outcomes. <http://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2015-2016/>

This dissertation demonstrated an unconventional approach to exploring engineering education and engineering ethics in a number of respects. First, it adopted an ethical framework (care ethics) that has not received much attention in the engineering field. It also employed an empirically-based approach to exploring engineering ethics, which both facilitated a deeper understanding of the ethical responsibilities of engineers and provided a baseline for understanding the ethical thinking of engineering students, who are the next generation of engineers. Furthermore, the context-dependent nature of the work¹¹ served to focus the analyses, thereby producing practical implications for education. I hope these aspects of the work contribute positively to the fields of engineering ethics, engineering education, and more importantly, to improving the practice of engineering. Some further ideas for practical approaches to care in engineering are provided in Appendix B.

¹¹ The context-dependent nature of the work is consistent with the care-ethical framework I adopted, which recognizes that the “right thing to do” is dependent on situational factors including the specific actors involved. Theorists looking for universal or widely generalizable claims might view this as a limitation, but if so, they may be missing some important dimensions of care ethics, namely, its practicality and the challenge it poses to abstract, universalistic approaches to ethics (see Held 2007).

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Appendix A. Publications Resulting

A.1 ARTICLES PUBLISHED

Campbell, R. C. & Wilson, D. (2016). Engineers' Responsibilities for Global Electronic Waste: Exploring Engineering Student Writing Through a Care Ethics Lens. *Science and Engineering Ethics*. <http://doi.org/10.1007/s11948-016-9781-2>

Campbell, R. C., Yasuhara, K., & Wilson, D. (2015). Ethics in Engineering Students' Design Considerations: Case Studies of Electric Power Systems for the "Developing World." In *Proceedings of the 122nd American Society for Engineering Education (ASEE) Annual Conference* (pp. 1–18). Seattle, WA, USA: American Society for Engineering Education. <http://doi.org/10.18260/p.24024>

Campbell, R. C. (2013). How Can Engineering Students Learn to Care? How Can Engineering Faculty Teach to Care? In J. Lucena (Ed.), *Engineering Education for Social Justice: Critical Explorations and Opportunities*, Philosophy of Engineering and Technology (Vol. 10, pp. 111–131). Dordrecht, Netherlands: Springer. http://link.springer.com/chapter/10.1007/978-94-007-6350-0_6

Campbell, R.C., Yasuhara, K., & Wilson, D. (2012). Care Ethics in Engineering Education Undergraduate Student Perceptions of Responsibility. In *Proceedings of the IEEE Frontiers in Education Conference (FIE)*, October 2012. <http://doi.org/10.1109/FIE.2012.6462370>

Campbell, R.C., Yasuhara, K., Atman, C.A., & Sheppard, S. (2012). Exploring If and How Knowledge of a Humanitarian Disaster Affects Student Design Thinking. In *Proceedings of the 119th American Society for Engineering Education (ASEE) Annual Conference and Exposition*. San Antonio, TX, USA: American Society for Engineering Education. <https://peer.asee.org/21373>

Campbell, R.C., & Wilson, D. (2011). The Unique Value of Humanitarian Engineering. *Proceedings of the 118th ASEE Annual Conference and Exposition*. Presented at the American Society for Engineering Education Annual Conference and Exposition, Vancouver, BC, Canada.

A.1 ARTICLES IN PREPARATION

Wilson, D. & Campbell, R. C. (2015). What Students Know about Solutions to Real Sustainability Problems: Electronic Waste. Manuscript in preparation.

Target journal: IEEE Transactions on Education.

Campbell, R. C., Yasuhara, K., Atman, C. J. (2016). Ethical Attentiveness in Engineering: Exploring How Knowledge of a Humanitarian Disaster Affected Undergraduate Student Design Thinking. Manuscript in preparation.

Target journals: Journal of Engineering Education and/or Engineering Studies.

Appendix B. Practical Approaches to Care in Engineering

One problem that now remains is to integrate an altruistic and interpersonal care ethics into engineering curricula so that engineers can learn to become the constructive agents of change many aspire to be. Pantazidou & Nair (1999) report struggling to identify examples in traditional engineering education that illustrate the applicability of the care ethic. In contrast with the military, industrial, commercial contexts in which engineering is predominantly taught and conducted (see Section 2.3), perhaps topics of humanitarian engineering and social justice are needed to bring care into engineering. Practical approaches to the practice of care in engineering may involve the development of skills and techniques that are unfamiliar to students in many engineering disciplines. Perhaps a human element is needed that both helps and requires engineers to care. In so doing, engineers will eventually come to realize that, because a “business as usual” mindset will provide no real solutions to problems that are fundamentally non-technical in nature (NRC 2012), changes in the structure and functioning of society will be required: changes they can then become involved in helping to effect. In this section, I briefly describe several practical approaches to care in engineering: techniques of stakeholder analysis, participatory design, and active listening. These are valuable and developmentally appropriate ways to bring engineers closer to various aspects of care ethics.

B.1 STAKEHOLDER ANALYSIS

As a first step toward a more caring engineering practice, stakeholder analysis is suggested as a means of preparing engineers to be more ethically caring in their work. Some examples of the use of stakeholder analysis for the purpose of qualitative data analysis were presented in each of the three preceding chapters along with suggestions for using it in teaching, learning, and educational assessment, but here I briefly discuss it in the context of engineering design. Because the language of stakeholder theory is business oriented, it provides a somewhat familiar learning experience for engineers, who may initially be uncomfortable with the idea of ethical caring and “soft” skills that it implies are needed. Stakeholder analysis requires first compiling a list of all the people, groups, and entities that affect or are affected by the decision or action being considered. For the purpose of ensuring social and environmental justice, non-human and non-living entities

may even be considered stakeholders, although often it is the human advocate groups for such entities who take their place in the analysis. In conventional business contexts, once stakeholders are identified, the next step is to analyze the relationships of proximity, power, and salience among the stakeholders, considering such things as level of interest, attitude, need, influence, and supportiveness. This analysis is often represented as a map or graphic illustrating the relationships of interest.

In terms of Tronto's framework, stakeholder identification & analysis provides a useful method for raising awareness of the needs of others (i.e., Tronto's Attentiveness) by helping to identify less visible stakeholders and thereby anticipate unintended consequences. It also is helpful in identifying the power relationships that are present in the situation, and thus reveals risks of paternalism and exploitation thereby improving Responsiveness. While an exposition of stakeholder theory is beyond the scope of this chapter, it suffices to say that, as an outcome of the literature on strategic management, it attempts to solve the problem of the dichotomy of business and ethics (Freeman et al. 2005), which has historically required businesspeople to engage in emotional compartmentalization by requiring one ethic (or lack thereof) for business decisions and another for the rest of life. Its parallel with Tronto's framework and the dissolving of the public/private dichotomy should be clear. Because of its attention to relationships, context, and power, stakeholder theory has found much in common with care ethics and is viewed by several authors as being very closely aligned (Burton & Dunn 1996; Engster 2011; Palmer & Stoll 2011).

B.2 ACTIVE LISTENING

Another possible next step toward a more caring engineering practice is the development of active listening skills. Active listening is a technique that seeks to improve communication by training the listener to comprehend, retain, and respond competently when listening for various purposes, such as gaining information, performing critical analysis, and empathizing with the speaker (see Rothwell 2003, Chapter 7). Particularly the skills of informational and empathic listening are essential to such practices as participatory design, which is described in the next subsection. Informational listening requires us to put aside our preconceptions and biases, and listen carefully to what is being said to ensure that we gain accurate information. This is clearly a

prerequisite for the Attentiveness and Competence elements of Tronto's framework, since misunderstanding the need is not likely to result in effective care work. Similarly, empathic listening, with its associated responses of supporting, probing, and understanding, requires us to take the perspective of others, listen for what they need, and respond with appropriate sensitivity. These clearly correspond to Tronto's elements of Attentiveness and Responsiveness. Common non-empathic responses that seek to evaluate, advise, or interpret are much more likely to miss, devalue, or even distort the other's intended meanings, which in the case of participatory design (see below) would result in very poor outcomes. Finally, while active listening is perhaps a necessary and developmentally appropriate first step toward training engineers to be better communicators, Leydens & Lucena (2009) show how basic active listening skills may be insufficient when engaging in humanitarian engineering or social justice work and a more refined skill of "contextual listening" is in fact needed.

B.3 PARTICIPATORY DESIGN

The last approach to care I will discuss is the notion of participatory design as a means of preparing engineers for ethically caring engineering work. Participatory design, also known as cooperative design or co-design, emerged out of Scandinavia in the 1970's in response to a desire for a democratic industrial work-place (Ehn 1993). Unlike traditional design approaches, which rely on the knowledge and experience of expert designers working alone or on project teams in isolation from the end users, participatory design involves potential end users directly even in the early stages of design. The purpose is usually to avoid the problems of usability that invariably arise during product and system testing and to create innovative products that actually meet the users' needs. Participatory design is commonly used in a variety of fields, including community planning (Toker 2007), informatics (Carrol & Rosson 2007), architecture (Luck 2007), and to some extent software development (Mao et al. 2005; Hendry 2008). However, participatory design is not well known outside of engineering fields like human-centered design & engineering and computer engineering, and even there it may be viewed as an extreme form of user-centered design or even perhaps confused with usability testing (Mao et al. 2005).

In terms of Tronto's framework, participatory design similarly facilitates care in engineering practice by providing a mechanism whereby improved Attentiveness, Competence, and Responsiveness can be achieved through dialog with the community. Such dialog, if it occurs with an attitude of equality and respect (i.e., Gadamer's third mode of relating to others – see Section 2.4.2) using techniques of active listening with the appropriate stakeholders, can set the stage for potentially remarkable collaborations and outcomes that may even contribute to social and environmental justice.

Appendix C. Summary of Research Questions

RESEARCH QUESTION 1 (RQ1)

How might care ethics manifest in engineering?

RESEARCH QUESTION 2 (RQ2)

In terms of care ethics, how do students in traditional engineering programs respond to problems of humanitarian or social justice nature? Specifically:

RQ2-A:

How do students exhibit Attentiveness (“caring about”) in the context of natural disaster prevention?

RQ2-B:

How do students exhibit Responsibility (“taking care of”) in the context of “backyard” e-waste recycling?

RQ2-C:

How do students exhibit Responsibility in the context of rural electrification?

RESEARCH QUESTION 3 (RQ3)

What are the implications of the above (e.g., on course design, curricular change, educational policy, engineering practice)?

Appendix D. Codebook for Katrina/Attentiveness Coding

This appendix supports Chapter 3.

D.1 CODEBOOK FOR IF (I.E., WHETHER) KATRINA KNOWLEDGE INFLUENCED DESIGN TASK

This appendix supports Section 3.2.1a and Section 3.3.1.

D.1.1 CODING OBJECTIVE (IF)

The coding objective is to capture student indications of if (i.e., whether) Katrina knowledge consciously affected approaches to the design task using three codes: yes, maybe/ambiguous, or no. In most cases, this information will be in the form of direct responses to the protocol question (Q8). However, sometimes there are indications of how or why Katrina knowledge affected responses that clearly provide this information albeit indirectly. To arrive at a final code for each transcript, the following sub-objectives will be observed:

Sub-Objective 1

The first sub-objective is to capture initial indications of if (i.e., whether) Katrina knowledge consciously affected approaches to the design task. Each student's initial response indicating this will be coded, since it is the least influenced by the rest of the interview and the further thought / reflection that may occur while responding to:

- a) the Katrina-related protocol questions Q7 & Q8,
- b) follow-up questions (e.g., ""if so please describe"" following Q8), or
- c) any remaining interview protocol questions (e.g., in cases where the interviewee mentioned Katrina influence prior to or without being asked Q8).

Sub-Objective 2

The second coding objective is to capture indications of changes in response. Such changes may be due to further thought/reflection both while responding as well as during the course of any remaining interview questions.

Sub-Objective 3

The final coding objective is to arrive at a single code applied to the ""End of Transcript"" line at the bottom of each transcript that captures its final position on if (i.e., whether) Katrina knowledge influenced the design task. In most cases, this will be a repeat of the previous code application, but in some cases, a holistic view of the preponderance of the evidence may be needed to reconcile the statements and evidence available.

D.1.2 CODING METHOD (IF)

Interview transcripts will be read starting at the locations indicated by the following codes:

Q8-Did_Katrina_Affect_Response, QX-Other_Q_that_Triggers_Katrina

and ending when the topic changes away from Hurricane Katrina. The starting points for each transcript (i.e., ""Primary Document"") are visible in the ATLAS.ti margin area and can also be located via the code in the Code Manager.

Note, however, that

- A) transcripts may have multiple sections in need of coding, and
- B) if an interviewee's response is unclear (e.g., due to pronoun use or references to something mentioned previously), the necessary context should also be read so that the response is comprehensible.

Q8-Did_Katrina_Affect_Response

Post-task Question (part of the post-task reflection interview protocol)

Q8: Did what you know about these events affect how you approached the Mississippi flooding activity today? (If so, please describe.)

QX-Other_Q_that_Triggers_Katrina

Questions, other than Q8, that prompted mention of Hurricane Katrina as having affected design task responses.

D.1.3 CODE DEFINITIONS (IF)

a_if_Ambiguous/Maybe

The ""Ambiguous/Maybe"" code is applied to responses that are UNCLEAR or "ON THE FENCE" in indicating if (i.e., whether) Katrina knowledge affected design task responses. Note that this differs from connotations of both limitation and firmness/softness. Examples why this may occur include:

- Interviewee expressed unresolved equivocation in self-report
- Interviewee neglected to answer the question
- Interviewee gave irrelevant/tangential response
- Interviewer did not follow up to clarify (e.g., in unprompted mentions of Katrina)

n_if_NO

The ""No"" code is applied to responses that are NEGATORY in indicating if (i.e., whether) Katrina knowledge affected design task responses. Degree or qualifications of this non-influence are not distinguished, thus this code applies to responses that are:

- a) confidently negative (e.g., ""Definitely not.""),
- b) unqualified negative (e.g., ""No.""), and
- c) qualified negative (e.g., ""Not really.", ""I don't think so."").

y_if_YES

The ""Yes"" code is applied to responses that are

AFFIRMATIVE in indicating if (i.e., whether) Katrina knowledge affected design task responses. Degree or qualifications of influence are not distinguished, thus this code applies to responses that are

- a) confidently affirmative (e.g., "Oh yes!"),
- b) unqualified affirmative (e.g., "Yes."),
- c) qualified affirmative (e.g., "A little." and "I think so").

D.2 CODEBOOK FOR HOW KATRINA KNOWLEDGE INFLUENCED DESIGN TASKS

This appendix supports Section 3.2.1a and Section 3.3.2.

D.2.1 CODING OBJECTIVE (HOW)

The coding objective is to classify student self-reports of how (i.e., in what ways) Katrina knowledge affected approaches to the design task using high-level, empirically derived codes. The code names are: Design Approaches, Natural Environment, People/Society, Designed Artifact (i.e., the retaining wall), Other, and Ambiguous. Each of these codes is defined below and includes examples. Multiple codes may apply to any given response or portion thereof. Comprehensive coverage of all applicable codes is desired for each response, which means that each individual instance of a code will be tagged separately (e.g., if wall strength, wall longevity, and wall quality are all mentioned, then the Designed Artifact code will be applied 3 times). Note: Responses should generally be interpreted literally, without reading too much into them.

D.2.2 CODING METHOD (HOW)

Interview transcripts will be read starting at the locations indicated by the following codes:

Q8-DidKatrinaAffectResponse

QX-KatrinaPromptedByOtherQ

and ending when the topic changes away from Hurricane Katrina. The starting points for each transcript (i.e., ""Primary Document"") are visible in the ATLAS.ti margin area and can also be located via the code in the Code Manager.

Note, however, that

- A) transcripts may have multiple sections in need of coding, so it is important to scroll all the way to the end,
- B) if an interviewee's response is unclear (e.g., due to pronoun use or references to something mentioned previously), the necessary context should also be read so that the response is comprehensible,
- C) the lead-in question PTQ7 ("what do you know about Hurricane Katrina") will not be coded and may not be read unless necessary (e.g., see B above).

Q8-DidKatrinaAffectResponse

Post-task Question (part of the post-task reflection interview protocol)

Q8: Did what you know about these events affect how you approached the Mississippi flooding activity today? (If so, please describe.)

QX-KatrinaPromptedByOtherQ

Questions, other than PTQ8, that prompted mention of Hurricane Katrina as having affected design task responses.

D.2.3 CODE DEFINITIONS (HOW)

a_KatHow_Ambiguous

Indications that Katrina knowledge affected design task response, but are AMBIGUOUS in describing how they did so.

Examples why this may occur include:

- Interviewee neglected to mention how
- Interviewee gave irrelevant/tangential response
- Interviewee could not articulate how
- Interviewer did not follow up appropriately

d_KatHow_DesignApproaches

Indications that Katrina knowledge prompted consideration of DESIGN APPROACHES, i.e., how design is done / aspects of the process of design (not attributes of the resulting design/artifact or artifact-centric activities, which are covered by "Designed Artifact").

Examples include:

- Concretize the Abstract (making it real)
- Similar Incidents
- Design Safety Margins (considered)
- Unintended Consequences
- Failure Issues
- Urgency (timeline)
- Learn from Other's Mistakes
- Worst-case Scenarios

n_KatHow_NaturalEnvironment

Indications that Katrina knowledge prompted consideration of the NATURAL ENVIRONMENT, i.e., the ecosystem and/or components thereof.

Examples include:

- Climate / Weather
- Ecosystem / Environment
- Flood Intensity
- Topography / Terrain
- Water Conditions

o_KatHow_Other

Indications that Katrina knowledge prompted consideration of something unambiguous and OTHER than the categories above (i.e., not captured by Design Approaches, Natural Environment, People/Society, Designed Artifact, or combinations thereof).

p_KatHow_People/Society

Indications that Katrina knowledge prompted consideration of PEOPLE/SOCIETY, i.e., interactions between the design and people/society in any direction of influence (e.g., humans being affected by the design, as well as the design being affected by humans).

Examples include:

- Flood Victims
- Government
- Neighboring Communities
- Political Impacts
- Population Density
- Project Economics (who pays for it)
- Project Team (designers, engineers, etc.)
- Protecting People
- Social Demographics
- Social Impacts
- Workers/Jobs

w_KatHow_Wall(DesignedArtifact)

Indications that Katrina knowledge prompted consideration of the DESIGNED ARTIFACT (the retaining-wall itself), i.e., attributes of the wall and/or wall-centric activities.

Examples include:

A) Attributes

- Wall Aesthetics
- Wall Base Elevation
- Wall Cost
- Wall Dimensions
- Wall Lifetime
- Wall Location
- Wall Materials
- Wall Quality
- Wall Repair Ease
- Wall Strength

B) Wall-centric Activities

- Wall Construction Ease/Speed
- Wall Maintenance
- Wall Monitoring

D.3 CODEBOOK FOR CARE-ETHICAL ATTENTIVENESS OPERATIONALIZATION

This appendix supports Section 3.2.1b and Section 3.4.

D.3.1 CODING OBJECTIVE AND DEFINITIONS (ATTENTIVENESS)

The coding objective is to classify, from the perspective of care-ethical Attentiveness, student self-reports of how (i.e., in what ways) Katrina knowledge affected approaches to the design task. For the purpose of this portion of the analysis, Attentiveness will be operationalized in terms of awareness of needs and/or others with needs and designated passages will be coded as citing:

- (0) Neither Others nor Needs (passages that show neither awareness of needs nor of individuals, groups, institutions or entities, e.g., human, animal, plant, river, ecosystem, who are in need).
- (1) Others (explicit indications of specific individuals, groups, institutions or entities, e.g., human, animal, plant, river, ecosystem, who are in need, noting that here the need may be implied).
- (2) Needs (explicit indications of specific needs held by individuals, groups, institutions or entities, e.g., human, animal, plant, river, ecosystem).

Note that because a given passage may show indicate both others and their needs, codes 1 and 2 are not mutually exclusive, thus some passages may be coded with both 1 and 2. Code 0, however, is mutually exclusive. Thus, once coding is complete and each passage tallied, care-ethical attentiveness will ultimately be operationalized in terms of passages citing a) both others & needs, b) only needs, c) only others, and d) neither others nor needs.

D.3.2 CODING METHOD (ATTENTIVENESS)

Interview transcripts will be accessed in ATLAS.ti starting at the locations indicated by the Area of Concern (AoC) codes previously applied. Since Attentiveness as defined above is often unclear from the quotes as delimited by the AoC code applications, the preceding context (e.g., including responses to PTQ7 "what do you know about Hurricane Katrina") and any following context (e.g., until the topic is no longer related to Hurricane Katrina) will also be read with an eye toward

clarification of the ideas identified in that Area of Concern code application. Similarly, if the quote itself is unclear due to pronoun use or references to something mentioned previously, the necessary context will be read so that the response is comprehensible.

Based on this contextual reading, the appropriate Attentiveness code(s) (i.e., either 0, 1, 2, or 1+2) will then be applied to the entire section of text that was used to make the Attentiveness determination. The coder will keep in mind that quotes/passages outside the direct response to PTQ8 (if/how Katrina influenced design tasks) must be read carefully and used only when they clearly relate to (e.g., explain or expand on) the way Katrina affected design task response (as highlighted by the associated AoC code).

Due to the nature of the AoC categories, for quotes under People/Society and Natural Environment, indications of needs and others who have them are usually clear and direct when they are present. However, for quotes from the Designed Artifact (Wall) and Aspects of Design Approaches categories, coding must be based on explicit indications of relationship between the wall or design consideration and the need and/or entity in need.

For book-keeping purposes (i.e., organizing and writing up the findings, plus later ease of reference), a separate Attentiveness code will be used with each Area of Concern. While each code will have the same definition, it will aid in distinguishing the original type of AoC with which it is associated.

Note that multiple AoC's of the same type (e.g., wall dimensions, wall materials, and wall strength) may all be captured under the same Attentiveness code (i.e., each indicating awareness of the same entity(ies) and/or need(s)).

Appendix E. Mapping Empirical Stakeholder Codes to Benchmark Categories

This appendix supports Chapter 4, Section 4.3.1. Table 15 below provides details of the mapping between my inductively derived stakeholder codes and the benchmark categories of Table 11. In performing this mapping, I referred back to the student essays to clarify the context and meaning of any stakeholder invocations that were potentially ambiguous to ensure that they were mapped appropriately. For example, the inductive code “Laborers” could be interpreted to fall under many categories, but the students in this data set all invoked them as recycling facility workers and thus Recyclers was the only appropriate benchmark category. In some cases, two benchmark categories applied because of differences in the specific quotes comprising the codes. For example, in the inductive “Retail Sellers” code, two essays indicated the distribution function of retail stores, while a third essay invoked them to suggest implementing take-it-back programs, thus calling for the addition of the Collectors benchmark category. A similar situation existed for the inductive “Distributors of Electronics” code. Note also that there were also several inductive categories that did not fit the benchmark categorization for a variety of reasons, such as they were too broad (e.g., Society, Market Forces), too vague (e.g., everyone) or they referred to non-human entities (e.g., the natural environment).¹ These appear in the third column of the table labeled with “NA”.

Table 15: Mapping Empirical Stakeholder Codes to Benchmark Categories

Inductive Stakeholder Category	Inductive Stakeholder Code	EMPA / UNU-StEP Stakeholder Group Category
Technical/ Economic	Businessmen	Manufacturers & Importers
	Companies	Manufacturers & Importers
	Companies-Developing Country	Manufacturers & Importers
	Companies-Electronics	Manufacturers & Importers
	Companies-Other	Manufacturers & Importers
	Consumers of Electronics	Consumers
	Distributors of Electronics	Distributors; Collectors
	Employees-Industrialized Country	Manufacturers & Importers
	Engineers	Manufacturers & Importers
	Engineers of Future	Manufacturers & Importers

¹ See my comment in Section 4.3.1 (associated with Footnote 12) about the Natural Environment as a stakeholder.

Technical/ Economic	Factories-Developing Country	Manufacturers & Importers
	Factory Workers-Industrialized Country	Manufacturers & Importers
	Industry-Electronics	Manufacturers & Importers
	Innovators	Manufacturers & Importers
	Laborers	Recyclers
	Manufacturers	Manufacturers & Importers
	Market Forces	NA
	People-Greedy	Manufacturers & Importers
	Producers-Electronics	Manufacturers & Importers
	Recyclers-Developing Country	Recyclers
	Recyclers-Industrialized Country	Collectors
	Recyclers-Unclear	Recyclers
	Retail Sellers	Distributors; Collectors
	Scientists	Civil Society
Citizenry	Anyone in Contact	NA
	Children	Most-Affected Communities
	Cities	Most-Affected Communities
	Communities	Most-Affected Communities
	Consumers-Food	Most-Affected Communities
	Everyone	NA
	Farmers	Most-Affected Communities
	Future Generations	Most-Affected Communities
	Humans	Most-Affected Communities
	Parents	Most-Affected Communities
	People	Most-Affected Communities
	People-Innocent	Most-Affected Communities
	People-Near Recycling and/or Disposal	Most-Affected Communities
	People-Not Part of Decision	Most-Affected Communities
	Public	Consumers
	Schools	Civil Society
	Self	NA
	Self+Others	NA
Society	NA	
Students	Civil Society	
Natural Environment	Environment	NA
	Fauna	NA
	Flora	NA
Governmental/NGO	Countries-Developing Country	Governmental Agencies
	Countries-Industrialized Country	Governmental Agencies
	Government-Developing Country	Governmental Agencies
	Government-Industrialized Country	Governmental Agencies
	Government-Unspecified	Governmental Agencies
	Legislators	Governmental Agencies
	Policy Makers	Governmental Agencies
	NGOs	Civil Society
	Professional Groups	Civil Society

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