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ORIGINAL PAPER

Pragmatism and Care in Engineering Ethics

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Abstract

Engineering is a practice that must function in an environment of incomplete and uncertain knowledge. This environment has become even more difficult in an increasingly complex world. Engineering ethics has to be framed and taught in a way that addresses these realities. This paper proposes a combination of the philosophy of pragmatism and the ethic of care as a possible framework for the practice of engineering ethics that can provide flexibility and openness to address engineering ethics problems more realistically within the ethos and culture of engineering. Embedding values into practice, pragmatism and care provide a broad, reflective, and corrective framework for engineering ethics that can accommodate the realities in which engineering operates. It is shown that these two approaches are more consonant with design methodologies and have a natural fit with design thinking, so they mesh well with what engineers do and with the complexities of their work today. As humans more and more try to alter the socio-techno-natural world, e.g., the earth's climate, the combination of pragmatism and care will allow enhanced ethical behavior. Alterations to complex adaptive systems will produce highly uncertain results that require engineers to have a mindset that allows them to act with humility in the face of significant uncertainty and potential catastrophic failures.

Keywords Care · Engineering education · Engineering ethics · Pragmatism

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Introduction

This paper considers the philosophical principles of pragmatism and the ethic of care as providing a broad framework for engineering ethics that can accommodate the realities in which engineering operates. It should be possible to construct a flexible, adaptable framework for the purpose of engineering ethics that integrates the two. Pragmatism and care can contribute to addressing thorny problems—simple and complex, local and global—that engineers of today face. These two approaches are more consonant with design methodologies, and hence should already be somewhat familiar to engineering faculty. They have a natural fit with design thinking, so they mesh well with what engineers do.

Engineering ethics education should integrate seamlessly into engineering education. In general, formal academic engineering ethics, especially as it is taught today, has evolved by looking at philosophical theories that can form a basis to uphold the primary engineering obligation of "keeping public safety paramount" while working to design a solution under a range of constraints and often significant uncertainty.

Teaching engineering ethics and articulating engineering ethics for practice have both gained importance in the last three decades. Originally, engineering ethics was defined solely by engineering professional societies through their canons translated into codes or rules of practice (NSPE 1). Prior to the 1980s, most engineering students encountered ethics only in the form of the codes they needed to know for the Professional Engineer examination. There was no required course or any kind of instruction in engineering ethics in the undergraduate curriculum. Part of this ethos came from the identity of the engineering field.

Identity of Engineering

The ethos of engineering is necessarily one of practical action. Engineering is about working within external constraints, and engineering practice is based on a way of thinking that is not limited to applied science, but rather encompasses an evolving set of heuristics that can be used to design engineering artifacts. William Bulleit (2015) calls this the *engineering way of thinking*. Several authors have articulated the importance of considering all aspects of engineering, as well as the interactions of engineers and engineering with the rest of society, in building a usable framework for engineering ethics. Herkert (2005, p. 373) has pointed out the importance of engineering ethics including "*microethics* (concerned with individuals and the internal relations of the engineering profession) and *macroethics* (concerned with the collective, social responsibility of the engineering profession and societal decisions about technology)". Schmidt (2014, p. 1008) has proposed a framework based on virtue ethics that addresses "what engineers do, how they do it, and why it matters".

The rules of professional practice in engineering until the early 1900s were conditioned by the fact that engineers looked on themselves as loyal to a firm or a larger entity such as the military or public works that employed them. Historically, engineering as a field—rather than a "profession"—and then as an academic discipline, originated from these roots in the late 1740s with the establishment of the first "civil" (as opposed to "military") engineering department in France in the École Polytechnique in 1794 (Davis 1998; Grayson 1993). The American Society of Civil Engineers was founded in 1852 and is the oldest engineering society in the United States.

It was only in the 1930s that the engineering community in the U.S. began to assume autonomy as a profession and develop a professional identity. This change was reflected in engineering ethics and codes. Seven engineering societies jointly established the Engineering Council for Professional Development (ECPD, precursor of ABET) in 1932, and the National Society of Professional Engineers (NSPE) came into being in 1934. The key point here is the appearance of the term "professional" in reference to engineering. The code of ethics proposed originally by NSPE as far back as 1935 (adopted in 1946) included the phrase "protect the public health, safety, and welfare". It should be noted here that the licensing of engineers began in Wyoming in 1907 to protect the public from untrained individuals practicing engineering and surveying. In 1954, NSPE established the Board of Ethical Review, a panel of engineering ethics experts that has served as the profession's guide through ethical dilemmas.

As codes evolved over time, they reflected the principles under which engineers worked. These principles are fundamentally about helping society—including individuals or institutions—by technological means, under constraints of "time, information, and resources" (Trevelyan 2010, p. 188). These constraints are posed by schedule, costs, and other limitations associated with the social, natural, and institutional environments in which engineers operate. The set of codes was not based on philosophical theories, but on commonly shared beliefs in the engineering community about virtuous conduct in engineering practice.

Ethos of Engineering

The engineering ethos—or engineering way of thinking (Bulleit 2015, 2016a, b, c)—derives from the realities of engineering theory and practice. Engineering is a discipline of action "in time": conceiving, designing, making, doing, maintaining, and modifying. Engineering competence based on an evolving state of knowledge is the essential foundation of the engineer's work, and requires acknowledging and addressing the risk and uncertainty present under the specific design context. Cost, schedule, risk, and an ability to judge the balance of these, form the premises of the engineer's work.

The engineering way of thinking encompasses all useful tools regardless of the discipline. Engineering is *not* merely applied science, and it is a disservice, especially to students, to employ this often-used description. In fact, technology, the product of engineering embedded in society, derives its name from *techne*, which means art or craft in the sense of "cunning". Hardy Cross (1952, p. 2) wrote that engineers "use any fact or theory of science, whatever and however developed, that contributes to their art".

Practice is the heart of engineering, based on judgment and the best information available. Engineers today often work together in teams, rather than as individuals. They develop heuristics, including rules of thumb, that allow intractable problems to be solved in a manner such that the engineered product works in the context for which it was designed; and as these contexts and knowledge change, the heuristics evolve. This practical judgment is the defining characteristic of engineering, and includes an understanding of human and social interactions. Schmidt (2014, p. 990) cites Trevelyan's (2010) characterization of engineering as a "human social performance" that "relies on harnessing the knowledge, expertise and skills carried by many people, much of it implicit and unwritten knowledge. Therefore, social interactions lie at the core of engineering practice".

Hence the ethos of engineering is one that applies practical cumulative wisdom and judgment; its ethic is one of practical wisdom, having to act in the face of incomplete knowledge, assess risks, and learn from each experience, especially errors. This work has become more complex as societies, economies, and technologies get intertwined and engineering becomes deeply embedded in the resulting system. Martin and Schinzinger (1983) write of engineering as social experimentation, as the impacts of engineering work are tested out in society. The use of technologies in close interaction with humans, in relatively new spheres, has also given the field of engineering more intersections with biology and medicine. Thus, engineering ethics has also developed a significant overlap with bioethics.

Engineering Ethics

Engineering ethics as taught and framed primarily for teaching young engineers—it may be appropriate to call this academic engineering ethics—has been based on the canonical, long accepted philosophies, focusing almost exclusively on the precepts of utilitarianism and Kantian "respect for persons", often presenting them as dichotomous alternatives (Harris et al. 1995).

It is when engineering ethics entered undergraduate curricula that engineering *faculty* looked for "founding principles". The first theoretical frameworks developed by engineering faculty in collaboration with philosophers looked to philosophical ethics for such principles. The nature of engineering, including the one-to-many obligation because of the need to design for a group of people rather than a single client and the link of engineering to the economy, made the utilitarian principle an obvious choice as one of the principles on which to "base" engineering ethics. Yet recognizing the potential of technology to cause harm led to invoking the Kantian principle of people as "ends rather than means" as well. While textbooks mentioned other principles such as Rawls' theory of justice, these two—utilitarianism and Kant's "categorical imperative", translated as a version of the Golden Rule, remained the main basis of engineering ethics as taught. This was the case, for example, in the widely used textbook on engineering ethics by Harris et al. (1995). The other pioneering textbook, by Martin and Schinzinger (1983), framed engineering as "social experimentation" and chose three founding principles for ethics: awareness (of the consequences of the engineering project), autonomy (the engineer's right to make decisions), and accountability (assuming responsibility for the work).

Engineering ethics as articulated has challenges in being true to the working premise of the engineer. If an engineer were a single moral actor with an obligation of designing for one or a few individuals, then Kant's categorical imperatives could be followed. However, in most applications, the artifact is for the use and benefit of a large "public" and done under the frame of the utilitarian principle, often manifested as some kind of cost–benefit analysis both in public works and in many industries. Allen McDonald, one of the two engineers who tried to stop the launch of the space shuttle Challenger in 1986, told one of the authors that he found the one-to-many obligation of the engineer to the public as one of the most difficult challenges in practicing engineering (1990). McDonald said that this is the most salient difference between engineering ethics and medical ethics; the latter is premised on the one doctor to one patient type of obligation, under the tenets of patient autonomy, informed consent, beneficence, and non-maleficence. Adapting these long-established tenets of medical ethics as the founding principles was not possible because of the one-to-many obligation of engineering as compared to the one-to-one obligation in medicine.

An Ethics for Engineering

If people were starting afresh to articulate the tenets for engineering ethics today, how would they go about seeking the principles on which to found it? What qualities would be desirable—even essential—for such a foundation? What characteristics of the ethos, culture, and environment of engineering as a social enterprise would its ethics need to address? How can one base ethics such that it resonates with the "engineering way of thinking"?

As discussed above, there have been two lines of development of engineering ethics: One through the professional canons that dictate the professional code of ethics, and the other that emerged partly from the philosophy of technology, and from science and technology studies, and that crystallized in articulating engineering ethics in the context of the undergraduate education of the engineer. Herkert (2001) described these in terms of micro- and macroethics:

> Engineering ethics can be considered in three frames of reference—individual, professional, and social—which can be further divided into "microethics" (concerned with individuals and the internal relations of the engineering profession) and "macroethics" (concerned with the collective, social responsibility of the engineering profession and societal decisions about technology). Research and instruction in engineering ethics have traditionally focused on microethical issues and problems, and little attention has been paid to macroethics or the integration of micro-ethical and macro-ethical approaches. (403).

When one thinks of teaching engineering ethics—building the foundation for professional conduct of a new engineer—the distinctions above become striking. Good pedagogy and authenticity require that one articulate and approach such teaching as preparing students for behaviors consistent with the tenets, standards, and realities of the profession. As Weston (1992), like Dewey before him, points out, ethical conflicts are often taught not as true "problematic situations" set in a complex context, but rather as "puzzles" to be solved when the pieces fit together. The idea of "problematic situation" was first described by Dewey (1938, 107): "The indeterminate situation becomes problematic in the very process of being subjected to inquiry".

In the context of practice, pieces do not fit seamlessly without compromise. Frequently, the framing of the situation leads to a need to negotiate or decide between business or policy decisions based on economics, a utilitarian calculus, and a Kantian ideal of mutual respect for persons. In each of these, there is a presumed objectivity, independent of any specific relational context between people, and sometimes even independent of a situational context such as the type of organization or environment in which the issue is problematic. Frequently, when the relationship between people or the organizational context is taken out, the problem is trivialized. The real-world dilemma or problematic situation is reduced to a puzzle that does not fit with the complex reality.

One of the apparent problems with academic engineering ethics is that it is often taught by philosophers and ethicists who are not engineers and have no deep understanding of or connection to engineering practice. A professional engineer has recently called for a paradigm shift in engineering ethics to one based on virtue that addresses "what engineers do, how they do it, and why it matters" (Schmidt 2014). As he says, "a virtue perspective affirms that ethics is fully integral to the profession". Stated even more concisely: "Your practice *is* your ethics!" (1008). He uses the age-old philosophical analogy between virtues and skills. In this virtue ethic framework for "understanding and practicing the profession", Schmidt classifies the description of the requisite virtues under three central concepts of classical virtue ethics: *praxis*, *phronesis* and *eudaimonia*, covering the "What", the "How" and the "Why" of engineering.

Any ethics that is designed for engineering practice, and taught as engineering ethics, must have several properties. It must have the ability to:

- Deal with the societal ramifications of rapid technological adoption and change; i.e., social and technical systems in *flux*;
- Look forward *and* backward in order to project the impacts of this adoption and diffusion into the foreseeable future to the best of the current ability, and take first- and second-order effects into consideration. This means that students and professionals alike should possess a "historied view" (Margolis 1995): they should know about precedents and the background of empirical and experimental evidence, including failures, and have a sensitivity to contexts including aspects of human behavior. Students should know the stories of engineering, including concepts of risk and "normal accidents" (Perrow 1984)—not just told incidentally in a class lecture, but as part of the syllabus.
- Include and think about complexity in order to reflect on the possibility of unforeseeable consequences that might come from potential interactions and connections not considered primary to the design and functioning of the engineered system. One needs to teach about more than just safety factors and redun-

dancies. Students need to be introduced to uncertainty, including concepts of randomness and chaos, the importance of initial conditions and assumptions hidden in approximations, as well as emergence.
- Include and think explicitly about human dignity, including what aspects this technology might affect. To what extent does the technology help to maintain or even enhance human dignity?
- Think explicitly about the in situ lifetime of the engineered artifact. Although this is likely part of the previous points, neglecting time elements such as rates of change compared to time constants of natural processes and life cycles or histories has been consistently problematic, particularly for complex systems.
- Reflect often on the design criteria and constraints used in practice. In our fast-paced world, where technology and new knowledge about aspects of the engineering-society interface, such as health and environmental impacts, are developing rapidly, one needs a frame of mind that works in a continuous, practical, yet reflective examination of "what to do", not only in the face of emergencies, but as an ongoing habit.
- Recognize that engineering problem-solving generally is a community activity where input from all involved parties is a must. This implies that the engineer be a good communicator in both the local and global communities.

Simply put, engineering ethics should be taught in a way that bridges meta- and interdisciplinary, integrative, and reflective thinking. Extension of principles and putting them into practice under constraints is a time-honored practice in engineering, in fact its founding cornerstone. This should include the ability to recognize and use other disciplinary knowledge and skills as appropriate within the entire context for the practice of ethical engineering.

Such an ethics has to be *representational*, *functional,* and *aspirational*. First, ethics is representational in that it reflects and codifies a time-honored yet current ethos, the founding beliefs and practices of the society, and the profession in which it operates. Kant's categorical imperative is a loftier statement of the Golden Rule, a precept in virtually all religions and social thinking that keeps humans as a special species. It resonates with the thinking with which people have been brought up. Thus, these principles are representational and in their bases, instrumental, in the society in which humans operate. Almost all policy-making in the U.S. finds its logic or at least justification through a cost–benefit analysis based on utilitarianism. Recently, an environmental ethic of respecting and protecting nature and the environment has come to be included in engineering ethics and reflected in many codes of practice.

Engineering ethics has to be *functional* because decisions on design implementation and use have to be made concretely, in the face of uncertainty and in a potentially complex system. These decisions then have ethical underpinnings and implications at the individual and collective levels, both for the engineers and for the recipients and users of their work.

Modern philosophers like Hans Jonas (1985), Manfred Stanley (1981), and Charles Harris (2013) have challenged people to move away from the traditional approach of *preventive* ethics toward an ethics that is *aspirational* because of the obligations brought about by the power and pervasiveness of technology, and its potential to affect the global future. Harris (2013, 178) states that "aspirational ethics has to do with using technology to promote human well-being", a proactive rather than responsive stance. More recently, metaethics and system ethics have been proposed as ways to include practical considerations in a complex system (Hollander and Kahl 2010).

Rather than starting from philosophical principles and choosing the set on which to base engineering professional ethics, one should ask what philosophical principles best fit an ethics for the engineering professional, and for the profession as a whole, in order to operate with its ideals for society, consistent with the engineering way of thinking. The word 'thinking' here implies both thinking in the usual sense and doing. Engineering thinking requires not only 'knowing that' but also 'knowing how,' and knowing how requires considering what to do, trying it, and then reassessing based on the results of the trial; and so on. Dewey (1958, 222) recognized this meaning of 'thinking': "*Freedom* of thought denotes freedom of *thinking;* specific doubting, inquiring, suspense, creating and cultivating of tentative hypotheses, trials or experimentings that are unguaranteed and that involve risk of waste, loss, and error" (italics in original). Engineering thinking is essentially a part of doing. This statement of Dewey is also rich in the sense of its use of verbs that denote the series of doings rather than objects that make the heart of engineering.

Pragmatism and Care

Pragmatism and care are two schools of thought that originated in the United States. As broad systems, they accommodate a plurality of views, are relation- and context-sensitive, and can adapt to complex situations. These two schools seem to present philosophical methods that would help frame decisions consonant with engineering thinking and with engineers' obligations. Pragmatism and care will be jointly considered here as a basis to develop a framework for an ethics that is part of and consistent with engineering practice. Pragmatism and care do not displace the utilitarian/Kantian precepts or virtue ethics, but rather provide frameworks that can include them along with justice, broadening the perspective of ethics so that it is not dependent solely on following a few canonical principles.

Pragmatism

Pragmatism was first articulated in the late nineteenth century, when philosophy was not an academic discipline in the United States. Dewey's landmark work was in the 1920s. In the next decades, pragmatism became unpopular for a while as analytical philosophy became the trend in the mid-twentieth century, but made a comeback with new arguments from philosophers such as Rorty, Quine, and Putnam, although it still remains largely absent from most philosophy review courses. This paper will work from pragmatism's foundations as developed by the "classical" pragmatists: Charles Sanders Peirce, William James, and John Dewey. Their work contains tenets that to a great extent capture the realities of engineering (e.g., Bulleit 2017). These three founders framed pragmatism, each primarily from a particular lens: Peirce, scientific; James, psychological; and Dewey, social. Thompson (2002, 199) has called pragmatism an "occasional" philosophy, "Just as occasional poetry is created for special occasions … occasional philosophy is created for circumstances where the audience has a special expectation that configures and shapes what will be done in advance … the emphasis on problems and specific occasions is one feature that distinguishes pragmatism". Our "occasion" in this paper is the doing of engineering, reflecting both the opportunity of improving human living, but also putting it at certain kinds of risk. As Rorty (2010, 211) said, "pragmatists such as Dewey turn away from the theoretical scientists to the engineers and social workers—the people who are trying to make people more comfortable and secure, and they use science and philosophy as tools for that purpose". The beginnings of pragmatism can be seen as a working backward from the realities of scientific experimentation and of *making* democracy *work* to articulate a method of philosophical inquiry. In this sense, it is a truly "democratic philosophy". It is also a philosophy originating from, and driven by, actions rather than merely ideas.

The Cartesian framework with its dichotomies used *methodological* doubt as a route to *certain* knowledge. Engineering has to work with incomplete and even changing knowledge. The basis of pragmatism is to move away from dogmatic truths to answering questions by iterative, corrective responses when experience produces *genuine* doubt. Pragmatism formally entered philosophy as Charles Sanders Peirce's attempts to examine how people form and hold to their beliefs in his famous essay, "The Fixation of Belief" (1877). Peirce sought a philosophy that "imitated the successful sciences, proceeding from tangible premises" with the reasoning being not a chain of single links, but "a cable whose fibres may be ever so slender, provided they are sufficiently numerous and intimately connected" (Menand 1997, 5). Peirce (1904) wrote, "…the word *pragmatism* was invented to express a certain maxim of logic" that "involves a whole system of philosophy … The method prescribed in this maxim is to trace out in the imagination the conceivable practical consequences—that is, the consequences for deliberate, self-controlled conduct—of the affirmation or denial of the concept; and the assertion of the maxim is that herein lies the *whole* of the purport of the word, the *entire* concept" (56, italics in original). "This maxim is put forth neither as a handy tool… nor a self-evident truth, but as a far-reaching theorem" (57). "The general leaning of the results is… toward common sense, toward anthropomorphism" (58).

Peirce was trying to describe how *genuine inquiry* is a "response to the irritation that one feels in particular circumstances where one's beliefs have in some way failed" (Thompson 2002, 200). A person then builds this inquiry within a context or situation, proceeding from prior experience. This is what engineering does. The basis of engineering on state-of-the-art knowledge and feedback from previous designs is an attempt to do things better using what one has learned from previous versions or experience, even in the face of uncertainty.

Having described the pragmatic method, Peirce explained what considerations guided his principle of what he later called *pragmaticism* to distinguish his own system from certain ideas of James and others with which he strongly disagreed. In his essay, "How to Make our Ideas Clear" (Peirce 1878), he wrote what came to be known as the *pragmatic maxim*: "Consider what effects, which might conceivably have practical bearings, we conceive the object of our conception to have. Then, our conception of these effects is the whole of our conception of the object". (36). Thus, for Peirce, the meaning of a concept is established on the basis of the practical outcomes that would follow from it.

Perhaps because of his language, and perhaps because as a scientist he was really aiming to solve problems of experimental design, Peirce's work remained largely unnoticed until William James popularized it in his own way, despite Peirce's criticism and rejection of James's efforts. Peirce conceived pragmatism as a science of inquiry, logic, and scientific thinking. James, a medical doctor by training and author of the first American text on psychology in 1890, came at pragmatism as a psychology of ideas and necessary action. Thompson (2002) points out that, in *The Will to Believe*, James pressed us to "consider situations where remaining in doubt has consequences … He makes the cost of inquiry into a factor that is relevant to fixation of belief … The consequences of continuing to inquire create a source of agitation sufficient to reorient the entire effort. Under such circumstances, admittedly speculative and normative considerations must be brought to settle the issue" (202). This is similar to engineering where one *has to* act in the face of incomplete knowledge and externally imposed constraints. James (1981) called his version "radical empiricism" in a "pluralistic universe". As Bernstein (1988, 397) writes, "The type of pluralism that represents what is best in our pragmatic tradition is an *engaged fallibilistic pluralism*". This is also true of the problem space of the engineer.

"Philosophizing", writes Thompson (2002), again paraphrasing James, "can make the situation worse when its conceptualization of doubt, evidence and inquiry precludes the taking of needed action". (202) This tenet of pragmatism is like the obligation of engineering. Engineers must make decisions before all scientific questions have been answered. "Good enough" or "satisficing" decisions are necessary. The developed judgment of the engineer then yields a "heuristic", which the engineer uses as the basis for action in a specific situation. "The final signature of a heuristic is that its acceptance or validity is based on the pragmatic standard *it works or is useful in a specific context* instead of on the scientific standard *it is true or is consistent with an assumed, absolute reality"* (Koen 2003, 32, italics in original).

Inquiry also has to be grounded in real, experienced doubt, not just of individuals, but of whole communities. This means that pragmatic inquiry works on specific concrete problems, seeking solutions rather than trying to build large edifices or hierarchies (Keulartz et al. 2002). And in this, the inquiry has to allow multiple viewpoints, choosing what to focus on by the potential effectiveness for the problem at hand.

John Dewey is the third major founder of pragmatism. He was educated formally in philosophy. His reflections on democracy, political philosophy, and the role of experience in education, all at a time when philosophy in America was fluid, led him to question the "quest for certainty" and the "spectator theory of knowledge". Dewey (1888) wrote, "democracy is an ethical idea, the idea of a personality, with truly infinite capacities, incorporate with every man" (204). Dewey was a leader in primary educational, social, and political developments of his time. He started the movement of laboratory schools where experiential education was part of the academic learning environment.

Dewey's version of pragmatism, stated in "The Need for a Recovery of Philosophy", was intended to address "the problems of men" (Dewey 1917, 219). Dewey describes how values are defined as people look for ways to act, and that ethics is very much about action. Jafarinaimi et al. (2015) link industrial design and values through Dewey's lens: "Issues of design and values arise together when we encounter problems of how to serve the many demands of human life and living in particular and changing circumstance" (95). Their statements and analysis are very much applicable to engineering, as well.

Bernstein (1988, 385) characterizes the pragmatic ethos as "five interrelated substantive themes":

- *Anti-foundationalism* Peirce argues against the previous epistemological assumptions "that knowledge rests upon fixed foundations and that we possess a special faculty of insight or intuition by which we can know these foundations" (385).
- *Fallibilism* The alternative to foundationalism is a fallibilism "where we realize that although we must begin any inquiry with prejudgments and can never call everything into question at once, nevertheless there is no absolute belief or thesis—no matter how fundamental—that is not open to further interpretation and criticism". (p. 387) Hence his comparison of reasoning to "a cable whose fibres may be ever so slender, provided they are sufficiently numerous and intimately connected" rather than a "chain of claims which is no stronger than the weakest link" (387). For Peirce, philosophy is fallibilistic—"interpretative, tentative, subject to correction" (387).
- *Social character of the self* There is a need to have a critical *community* of inquirers: "We individually cannot reasonably hope to attain the ultimate philosophy *we* pursue" (387). Here Peirce meant the group of scientists and logicians involved in the inquiry. He thought that in the long run, there will be a convergence of inquiry. This is similar to the theme that Kuhn (1962) developed later as "paradigm shift". This social character also defines individuals as moral *agents* who bring their heuristics to all inquiry and solutions. There is a move towards accommodating a diversity of opinions, more global worldviews, and open dialogues to come to decision points: "It is only by the serious encounter with what is other, different, and alien that we can hope to determine what is idiosyncratic, limited and partial" (388). This implies a need for dialogue and coming to consensus in specific problems depending on the context.
- *Contingency and chance* Both of these are a reality. Before physicists arrived at quantum uncertainty, but after Darwin's theory of evolution, Peirce wrote that there is a "continuous interplay between evolving laws—habits of nature (or our interpretation of them)—and chance" (388). People need to have "awareness and sensitivity to radical contingency and chance that mark the universe, our inquiries, our lives" (388). Dewey expounded on this, writing that there is a "precariousness of existence" where the "world is a scene of risk", and this should condition our understanding of experience and even of philosophy (389). Hence the

pragmatists place emphasis on developing the complex of dispositions and critical habits that Dewey called "reflective intelligence" (389).

- *Plurality* There can be no escape from plurality. This follows from the social character of pragmatism, particularly as advocated by Dewey in a context larger than the scientific one that Peirce had in mind. Humans live in an "open universe" in which "infinite plurality is a characteristic of nature". This pluralistic ethos places new responsibilities upon each of us to understand the other.

While pragmatism provides an overarching frame for an ethical engineer's conduct, and pragmatic inquiry insists that one works on specific concrete problems, seeking solutions, it does not lay out steps to follow for a specific engineering project. The ethic of care can help provide such guidance.

Care

As a cultural, relational and religious concept, care has always been part of our daily vocabulary and people might say that caring is a species ethic, extending to animals as well. This paper seeks to use care as it has been formalized through articulation of an ethics of care. The "ethics of care" or "care ethics" is an ethical theory that has developed over the past three decades, originally based on obligations posed by relationships, as a complement to normative rule-based or deontological ethics. The idea of an ethic of care started with Gilligan (1982), who found that a large number of people, especially women, do not identify with moral responsibility when it is abstracted from context and relationships.

Like the virtue ethics of Aristotle, care begins with concrete human practices central in human life, but it has its basis in paradigmatic examples rather than in the attributes or virtues of an ethical person. Classical virtue theory starts with an account of what a good human life should be and works from there. Care starts with a relationship and the obligations it entails. Held (2006, 19) states

> …there are similarities between the ethics of care and virtue theory. Both examine practices and the moral values they embody. Both see more hope for moral development in reforming practices than in reasoning from abstract rules. Both understand that the practices of morality must be cultivated, nurtured, shaped … there are similarities between them and although to be caring is no doubt a virtue, the ethic of care is not simply a kind of virtue ethics. Virtue ethics focuses especially on the states of character of individuals, whereas the ethics of care concerns itself with caring relations. Caring relations have primary value.

Among the features both share, Groenhout (1998, 174) writes, is "a focus on states of character rather than rules or consequences … Caring, like virtue, is an inherently teleological practice, and cannot be considered apart from the ultimate goal of the practice". This meshes with several properties of the pragmatic outlook as described above.

Since its articulation, the ethics of care first gained use in health-care ethics, especially in nursing. It is a latecomer to engineering. In a review of care and care ethics in engineering education literature, Campbell (2013) writes that the earliest mention of care ethics in engineering was only in 1995, when electrical engineering professor Gene Moriarty (1995), publishing in the field of professional ethics, highlighted the importance of care tempered with objectivity, to create a balanced notion of both good engineering and the good engineer. In his later book, Moriarty (2008) elaborates on care not as a special *ethic*, but as an additional *virtue*, that of caring in a general way. Schmidt (2014) takes a similar approach, identifying care as one of three moral virtues specific to engineering, along with objectivity and honesty. Civil engineering educators Broome and Peirce (1997) stressed that "caring" is the motivation needed for engineers to become good, responsible, and even "heroic" in their practice. Kardon (2003) asks what is meant by the statement, "Engineers have a duty to provide their services in a manner consistent with the 'standard of care' of their profession". (7). Kardon has also explored in detail how 'standard of care' would have to be described so that, for example, juries would understand and interpret it consistently in a case where an engineer is tried for professional negligence. Based on interviews of structural engineers and case-based reasoning, he arrives at using jury instructions, derived from case law, as the framework with an "emphasis on care, diligence and best judgment" (118).

In the early instances, the idea of care was used as in common parlance: it was about "caring" about others in one's engineering work, rather than as part of a moral-ethical concern. An articulation by Tronto (1993), a political scientist, provided a framing of care and the ethic of care in a way that enables its systematic application to engineering practice. In an earlier work, Fisher and Tronto (1991) provided an overarching definition of care that lends itself particularly well to engineering:

"On the most general level, we suggest that caring be viewed as a *species activity that includes everything that we do to maintain, continue, and repair our 'world' so that we can live in it as well as possible*. That world includes our bodies, our selves, and our environment, all of which we seek to interweave in a complex, life-sustaining web" (40, italics in original). In invoking this definition, Tronto specifically clarifies that this definition "is not restricted to human interaction with others"; it is a reminder about engineering care expanding to include the natural environment. It is also worth noting that Fisher and Tronto include 'repair' as an integral part of caring. Spelman (2002) emphasizes the role of repair as a ubiquitous and vital part of everyday caring.

Tronto (1993) then sets about showing that the idea of caring for others far removed had entered philosophy earlier through the thinking of the "Scottish sentimentalists". The Scottish Enlightenment philosophers—David Hume, Adam Smith and Frances Hutcheson—introduced the notions of "moral sentiments" and "moral sympathy" as they thought about how to "preserve virtue when the earlier collective understandings of how to accomplish this end (solidarity) were no longer viable because of increasing social and geographic distance in human life" (36). The notion of sympathy arose in their works most famously in Adam Smith's *Theory of Moral Sentiments* (1759), the precedent to his much more famous *Wealth of Nations* (1776). For example, the idea of self-interest developed in *Wealth* is actually a route to developing sympathy leading toward "caring relations" as developed in *Sentiments*, rather than the self-centeredness that became the way that self-interest was eventually interpreted as the field of economics subsequently developed.

The ethic of care adapts well as a guiding framework for acting on complex problems. Tronto (1995) elaborated on the use of care in the practical matter of guiding political judgments and decisions: "For me, the question of which framework for moral and political thought is best is not so much an epistemological or logical question as it is a question about the prospects for creating a climate for good political judgments" (141). She continued that this is how Aristotle thought of the task of political science: "to make clear what the parameters and conditions are for individuals to make good judgments". (141) This is a central tenet for engineering ethics. Because of this, Pantazidou and Nair (1999) used Joan Tronto's (1993) characterization of the phases of care to demonstrate the correspondence between practicing care and engineering practice. Jones et al. (2015) explored how the elements of the care ethic can be used by middle managers for implementing sustainability objectives in chemical production, and the challenges for such leadership.

A care ethic emphasizes the importance of responsibility, concern, and relationship over consequences or rules. Care is not a system of rules or values; rather, it is value-guided *practice*. This orientation of care towards practice allows care and engineering to be treated in a parallel fashion. Similar to engineering solutions, care emerges as a response to a need. Moreover, care—ideally, like every engineering solution—explicitly acknowledges and equally respects all aspects of addressing a need.

Tronto (1993) provides the characterization of care that suits the engineering ethos. She identifies the process of caring as four phases: (1) *Caring about* is the phase of recognizing the (correct) need and realizing that care is necessary. (2) *Taking care of* is the phase that "involves assuming some responsibility for the identified need and determining how to respond to it". (3) *Care giving* is the phase where the need is met. (4) *Care receiving* is the phase where "the object of care will respond to the care it receives".

Tronto (1993) translates the four phases of care to the four elements of an ethic of care: *Attentiveness* (recognizing and assessing need), *Responsibility* (assuming responsibility to address the need), *Competence* (needed to design a response) and *Responsiveness* of the one being "cared-for" (designing the response, and seeing if it addressed the need appropriately). Total care requires an attuned caregiver who through commitment, learning and experience has an understanding of the process as well as the necessary competence and skills. She introduces a fifth component to the ethic of care, the *Integrity of Care*, requiring "that the four moral elements of care be integrated into an appropriate whole" (Tronto 1993, 136). The elements of care are combined at the appropriate levels to provide a solution with integrity and ethics.

Two authors have advocated the use of care ethics in concrete engineering venues. Kardon came at it through elaborating how the legal system interpreted the concept of 'standard of care'. Analyzing several case studies of engineering failure and liability, Kardon (2005) points out how the care element failed in each one. He concludes, "there is not a one-to-one mapping of the elements of care ethics onto the phase of engineering design, but that the presence of each of the five elements can be assessed at every phase of engineering, and in every engineering task". (22) Campbell (2013) discusses caring in engineering in detail, and will be elaborated on in a later section.

Empathy and Care

Care ethicist and philosopher Slote (2007) argues that the ethic of care is a "total approach to ethics" and not just "a complement to traditional thinking in terms of justice, rights, etc". (2). He combines the thoughts of moral sentimentalists on benevolence, compassion and sympathy with the literature on psychology to "argue that empathy is the primary mechanism" (4) for all these qualities and thus underlies caring. While sympathy as it figures in Adam Smith's work is feeling bad for someone, in empathy one feels what the other person feels. In caring, the empathy is projective, where one projects oneself into another's situation, rather than merely associative. He reviews various contexts such as social justice in which care is invoked. Slote concludes that empathy is helpful to a systematic employment of care-ethical ideas.

Campbell (2013) elaborates on "empathic caring" in his inquiry on "teaching and learning to care" in engineering. After a detailed treatment of the ethic of care, Campbell concludes that humanitarian engineering can provide "an important pedagogical tool for incorporating care as a missing dimension to engineering education" by promoting "altruism, cooperation, reflection/action and concern with addressing the non-technical root causes of problems rather than simply treating symptoms with technical fixes" (20).

In normal engineering ethics, especially as taught, the focus is mostly on the technical competence of the engineer. Care would say that technical competence is only *one* of the elements of competence. Competence should also include problem "finding", and examining whether the technological solution is the best, as part of the design process, and indeed of the engineering way of thinking. This is often impossible because the engineer is given the task of designing a technological solution as a given without having the autonomy to choose whether this is the best option for the overall problem.

Hess and colleagues (2017) explored how practicing engineers perceive empathy and care. In a later paper, they examine the role of "empathic perspective-taking" as the cognitive form of empathy and how it might work in a range of engineering contexts. More recently, Walther et al. (2017) have proposed empathy as a teachable skill, based on a review of the teaching of empathy in social work.

Pragmatism, Care, and Engineering Ethics

Pragmatic Method for Engineering Ethics

If one considers the pragmatic method as analogous in many ways to the engineering way of thinking, what kind of ethics follows? There is no fixed normative ethical theory that provides answers to engineering ethics issues, and pragmatism does not ask for one: “a pragmatic ethic is objective without being absolutist. It acknowledges that ethical judgments are relative (having to choose between options, say), without being relativistic. And it tolerates—indeed welcomes—some moral differences, without being irresolute” (LaFollette 2007, 216).

Pragmatism provides several precepts for engineering ethics:

1. *Context sensitivity* Pragmatism can accommodate insights from other ethical theories as a specific situation requires. For example, in public works projects, embedded in the social economy, cost–benefit analysis can be adopted as the calculus for economic and “public welfare” reasons. It should be emphasized that this does not mean that utilitarianism is a *basis* of engineering ethics. As the contexts in which engineers practice become more complex, the need to become a more reflective practitioner increases and pragmatism allows judgment and action to evolve together (Emison 2004).
2. *Fallibility* Pragmatism allows concepts to be “interpretative, tentative, subject to correction”, which can ground the ethic of engineers permitting action in the direction that appears best based on the knowledge possessed at this time, in this context, with “reasonable care and competence”. The feedback part of the cycle of engineering design is then an ethical requirement. But because of fallibility, ethical decision-making does not guarantee ethical results. Contingency and chance are always lurking. As Dewey (2008, 16) would put it: “The realm of the practical is the region of change, and change is always contingent; it has in it an element of chance that cannot be eliminated”.
3. *Agency* Pragmatism places an obligation on each of us, as social beings engaged in inquiry, to be agents in our context. This means that engineers must take responsibility to act in the best interest of those they serve, to be open to inquiry and revisions, to be competent in the methods of their profession and to update that competence continuously. Martin and Schinzinger (1983) have discussed the concept of moral autonomy—self-determining proficiency, awareness and sensitivity—as being requisite for an ethical engineer. As Dewey (1891) has said, “The breadth of action (as far as moral value is concerned, and not historical outcome) is measured by the insight of the agent. What are the conditions which require action, and what is the action which they demand? Just so far as this question is raised and answered, action is moral and not *merely* instinctive, or sentimental” (193, italics in original).
4. *Openness to multiple worldviews* The pragmatic nature of inquiry requires that engineers be open to alternative solutions and new ideas, and to the premise that a different answer than one they consider best may be better in a new context. This

> follows directly from a pluralistic worldview, and is a vital part of the engineering way of thinking. Virtue ethics also requires context-sensitive practical judgment (phronesis) to discern the best course of action in a given situation. Suckiel writes, referring to the work of William James, “Moreover, James makes the point that the main criterion for choosing among different kinds of descriptions is not whether one is truer than the other. Rather we look to see which description is more appropriate, given the purposes we have in view”. (Suckiel 1982, 132).

Care and Engineering Ethics

A good engineer cares. Consider Davis (2017): “Indeed, we might say that caring a lot about doing engineering well (an attitude) is part of what *constitutes* a good engineer” (188, italics in original). Kardon (2003) might say that the good engineer must meet the “standard of care” of the profession. If one also says that a good engineer must be an ethical engineer, then care is required to be a good engineer. The ethic of care points to a path that leads to caring. So, this section will consider how the ethic of care applies to practicing engineers and how it might be embedded in engineering ethics education. Stated in a more pragmatic way, the ethic of care is instrumental to engineering and the engineering way of thinking.

As one begins to embed care into engineering ethics, uncertainty and contingency must be kept in mind. As Dewey (2008) has said, “Practical activity deals with individualized and unique situations which are never exactly duplicable and about which, accordingly, no complete assurance is possible” (6). This context dependence is why engineering ethics is situational. Since engineering is contingent, by definition, there is always a danger of harm. “There is no engineering without harm; indeed, there is little any of us can do without some risk of harm” (Davis 2017, 189). Care is needed because engineering design is contextual and there is always a risk of harm, and, worse, some outcomes may occur through complexities in the system that cannot be predicted. Dewey (2008) recognized this aspect of practical activity: “Judging, planning, choice, no matter how thoroughly conducted, and action no matter how prudently executed, never are the sole determinants of any outcome” (6). Care can help us deal with these issues in an ethical manner, even though the possibility of unethical results always exists. Ethical decision-making is necessary but not sufficient for ethical results. One can never escape the possibility of harm.

Consider the first element, *attentiveness,* or *caring about* (Pantazidou and Nair 1999; Tronto 1993). This phase could mean caring about engineering, which seems obvious for an engineer; but more importantly, it means understanding the context and the population that would be most affected by an engineering solution, as well as the degree of the effects. This includes, for example, questioning whether the technological solution would indeed be the best one for the problem at hand. Technological solutions are generally presented as though they should work independent of the context, and this might pose the biggest problem for engineers who often are working to others’ prescriptions and decisions about the application of their designs. Students are rarely taught this, and many engineers ignore it. Goldman (1991) has referred to this as the “social captivity” of engineering, yet even the most socially captive engineer can consider the context of a potential engineering solution in order to mitigate negative effects within the boundaries set up by the decisions of others.

In the global context, this raises several issues including the labor conditions of the country in which the production is done and the nation and people for whom the solution is intended. But a teacher's obligation is to teach the whole story, including questions and issues that may remain unanswered for a while. The attentiveness phase of care would demand of engineering education a much larger scope of dwelling on the problem description and formulation phase than typically happens now.

The second element is *responsibility*, *taking care*. All design requires modeling and engineering decisions, often using codes of practice, as well as calculations, including those performed by computer software. All of these processes require that the engineer work with great care to minimize errors and poor decisions. This conduct is taking care and is an individualized task. From a moral or ethical standpoint, Dewey (1891) said, "Conduct is absolutely individualized… There is no such thing as conduct in general; conduct is what and where and when and how to the last inch" (191).

The third element, *competence,* or *care giving,* has a larger meaning including understanding the ramifications described above and taking this into account in the design of the process or product. It extends beyond the traditional notion of "being competent in engineering science, design and mathematics" to also knowing how to assess environmental or human risk, cultural needs and impacts, or at a minimum being aware of these factors and communicating to the user effectively.

A simple example of this enhanced conception of engineering competence is the approach of "green design", where the environmental impacts are taken into account in the design phase and the negative ones are minimized by design, rather than letting these happen by focusing only on the primary performance and cost of the engineered product and then mitigating the effects. But even in the traditional industrial ecology approach, the technological answer is considered as something that must happen; rarely does an engineering design get completely dropped altogether because of the deleterious effects. Furthermore, in green design, the human health effects are not always considered, especially in the face of uncertain risk. The accepted approach is to press on.

The fourth and final element is *responsiveness,* or *care receiving*. Pantazidou and Nair (1999) have suggested that this final element be modified to *assessment* to fit better with engineering. From an individualized and contextual perspective, assessment, as a minimum, means reflection on completed projects. Schon (1983) has suggested that reflection is one of the primary ways that practitioners can learn more about their practice. Reflection becomes a form of internal feedback, and an ethical practitioner will be a reflective practitioner.

Ethical Engineering Practice

In order to carry out the phases of a pragmatic care-based design with *integrity*, one needs to take into account the engineering-economic-ecological-human system, and make engineers aware of this nature of the engineering activity with the systems in which it is embedded. Engineering economics, as traditionally taught, is not enough. Thinking about the boundaries of the systems is vital. Many of these boundaries have been traditionally considered hard or impermeable because of practical reasons such as solvability of the problem, cost reasons such as not controlling pollution, or lack of knowledge about interactions, especially in engineering. Even when there is knowledge, such as that between technological byproducts and the natural environment, it has been conveniently ignored unless regulations enforce addressing them. Even then, industries have moved offshore to avoid these in the U.S., for example, with no concern for global well-being. Jonas (1985) points out that in view of the ability to model impacts, the technological imperative obliges us to consider the effects even when they may be distant in space and time. Care ethics requires that one incorporate this in the engineering solution.

The human part of the system is the least defined and least definable. For the engineer, it includes the individual human user and the community and society at large. This is where the global awareness of the engineer becomes important. While user studies and market research are done before launching a product, these are typically done only with regard to how sales can be increased, rather than how human well being in the local context may be made better (or worse).

This is a challenge; engineering has traditionally considered a problem in the abstract, with the human mainly as an interface issue for the purpose of making the product user-friendly, assuming that this means basically the same for all. The ideas of participatory design and co-design are growing in the field of industrial design (Prahalad and Ramaswamy 2004). Zoltowski and colleagues (2012) have used human-centered design as the focus for service learning, but engineering design still focuses primarily on the technical, even when considering the human interface.

Thus, in a pragmatic-care approach, it is imperative that engineers raise questions about risk and uncertain impacts. Engineers need to assume the role of asking questions about risk, making judgments under uncertainty, and then acting using the best available information to resolve seemingly intractable problems in an ethical manner. The engineering ethics text by Martin and Schinzinger (1983) addresses these aspects. This kind of thinking also makes a case for knowing the history of the issues at hand. Many problems that seem novel may have reared their heads or even been acted out by people in other situations. Having a worldview that includes historical knowledge aids in formulating the right questions and addressing context.

How engineers perceive empathy and care is central to understanding what pedagogies may help if people use the ethic of care to frame the work of engineering, and what ethical engineers do. Hess and colleagues (2017) and Campbell and colleagues (2015) have done exploratory empirical studies on this. They surveyed practicing engineers about the important aspects of engineering work environments and did a factor analysis of a 32-item section of the survey, focusing on empathy and care. The highest factor involved the relational aspects of engineering, including communication, working in teams, treating others respectfully, listening and meeting a client's need. While people might count some of these as aspects of care, direct questions about the importance of empathy and care on the practice of engineering showed that the engineers' awareness of these aspects is minimal.

Campbell and colleagues (2015) used a project in a developing world context that highlighted ethics and social justice between two neighboring states, one wealthy and one poor. They used the idea of "care-ethical responsibility" to examine whether the project reports of the two groups showed this characteristic. They found that while one group demonstrated "awareness, sensitivity, and appreciation of the expressed needs of the end user", the other group had a "more paternalistic approach suggestive of technological imperialism".

These exploratory studies would suggest that introducing the ethic of care explicitly, including participatory practice in addressing the engineer's professional responsibility, is an essential part of engineering ethics.

Pragmatism and Care in Practice

The best type of example to show how pragmatism and care complement each other is alteration of a complex adaptive system. To focus on an example, consider the earth's socio-climate system. The question, of course, is what steps does each segment of society take to deal with the changes occurring in the climate system. On a fundamental level, there are three approaches to consider: mitigation, adaptation, and do nothing. Engineering generally considers the first of these two as design issues. The decision about how much of each of them to use at any given time, and when is the best time to use any of them is the problem. Complex adaptive systems can be sensitive to local changes, potentially causing much larger failures than would be expected. Furthermore, since the system is adaptive, local alterations to the system may cause unintended consequences as the system adapts to the change.

As engineers begin to design and manage large complex systems, for example the earth's climate, a pragmatic mindset combined with care is the logical and ethical way to do so. In particular, the pragmatic tenets of fallibility, contingency, social character, and plurality have to be considered. Care principles that come to the fore are attentiveness, responsibility, and competence. Thus, decisions about how to alter the system must be done with the *fallible* nature of humans in mind. The effects of any change are highly uncertain and any changes to the system are *contingent* on the alteration being made. The selection of the type and size of the alteration requires *attentiveness* to the broad range of possible effects and a *responsibility* to respond to indications of failure in the system based on the choice made. Decision makers in engineering and policy will need a different mindset than what has been used in the past. They need a mindset that thinks of alterations to large scale systems as more maintenance than design (Bulleit 2018). This means that the pragmatic *social character* of the self needs to be part of any approach. Humans cannot continue to act as they have in the past: a paradigm shift is required. This shift means that decision makers must be fundamentally *competent,* but also must be *responsive* to both how they themselves behave and how the system behaves. In a real sense, the decision makers are simply a part of the overall system. And finally, any decisions about the system, whether it be mitigation, adaptation, or do nothing, will have potentially broad ranging effects on people, plants, animals, and the climate system. The *plurality* of these effects must be part of the new mindset. Humans will require the combination of pragmatism and care to address the increasingly complex systems with which we must deal, and a humility in the face of ignorance and uncertainty that seems missing today.

Conclusion

This paper has shown that it is possible for pragmatism and care to become part of engineering ethics. In a broader sense, one can consider an engineering way of thinking that goes beyond today's boundaries of engineering and suggests the relevance of weaving the strands of pragmatism, care, and virtue into engineering practice. In the age of global technology, paying attention to the context does not lead to a single solution, but does point out that there are limits to the possible solutions. The plurality and specificity requirements of the pragmatic method would also indicate this. Engineers need to be able to perform ethically in professional situations, even under the contingency that is unavoidable in engineering design. A framework that incorporates the ideas from pragmatism and the ethic of care can provide a background for engineering ethics that will allow a more reflective practice founded on a broader view of engineering.

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