Framing Engineering Ethics Education with Pragmatism and Care: A Proposal

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Dr. Bulleit teaches undergraduate and graduate courses in structural engineering. He received the University Distinguished Teaching Award for an Assistant Professor in 1986 and was one of top five candidates for the Distinguished Teaching Award for an Associate Professor or Professor in 1996, 1997, and 2014. He has been involved in a wide range of research in structural engineering, including reinforcement of wood materials, reliability of wood members and wood structural systems, design of traditional timber frame structures, development of structural design code criteria, and computational intelligence. Much of his research and teaching has considered the need for engineers to make decisions under uncertainty, and it was this portion of his work that led to an interest in philosophy and other nontechnical aspects of engineering. He has published over 100 technical papers. Dr. Bulleit is also the co-author of a textbook with Dr. Sheryl Sorby entitled, An Engineer's Guide to Technical Communication, published in 2006 and subsequently translated into Dutch, and he was the editor of a book published by ASCE entitled Classic Wood Structures.

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ABSTRACT
This paper considers the philosophical principles of pragmatism and the ethic of care as a broad framework for integrating ethics in undergraduate engineering. We propose an approach to integrate ethics into the teaching of engineering that accommodates the realities in which engineering operates and can bring up ethical considerations naturally. Increasingly engineering educators have been looking for ways to bring multiple affective perspectives smoothly into classroom and field practices of the student experience. Engineering is about working within external constraints and engineering practice is based on a way of thinking that is not applied science, but rather an evolving set of heuristics toward better design. Bulleit (2015) calls this the "engineering way of thinking" (EWT). A usable framework of engineering ethics should complement this, and include microethics, the engineer's individual responsibility and macroethics, which deals with the collective responsibility of the profession (Herkert 2001). Schmidt (2013) proposed an ethical framework based on virtue ethics that addresses "what engineers do, how they do it, and why it matters". Pantazidou and Nair (1999) articulated how the ethics of care fits naturally within the process of engineering design. Kardon (2015) examined how the legal definition of "standard of care" fits with engineering practice. Bulleit (2017) explored the similarities between engineering and pragmatism to show how pragmatism fits with the EWT.

A combination of two American-born philosophical worldviews – Care and Pragmatism - provides flexibility and openness to address professional ethics realistically within the ethos and culture of engineering. Care and pragmatism are both systems for action and practice. They embed values into practice, promote reflective thinking, are cognizant of the context, and emphasize the need for thinking about the practical consequences of an action. Because of this, they are open in definition and are flexible, aspects that are hard to navigate in the current ways of teaching the issues in engineering ethics, based on traditional philosophical frameworks.

As engineered systems become more complex, determining whether a decision is ethical becomes problematic due to the extreme uncertainty about the future. Furthermore, the decisions being made affect the future, but so do other events out of the control of the designer, and some of those events may be produced by the system being built. Whether a decision is ethical is particularly problematic in the design of large-scale engineered systems, including complex and complex adaptive systems such as social-technological-natural systems like the earth.

This paper is a reflective proposal. It reviews recent work and asks how care and pragmatism can articulate and contribute to addressing thorny problems– simple and complex, local and global-- that engineers face. We review recent empirical work on the ethics of care and the role of empathy in engineering. Campbell (2013) asked how engineering "professors can teach students to care". Other work (Walther et al. 2012; Hess et al. 2014) has begun to build a background of how we could begin this integration. We suggest that these approaches are more consonant with design approaches and hence familiar to engineering faculty. Engineering ethics can then integrate seamlessly into engineering education.

This paper considers a combination of the philosophical principles of pragmatism and the ethic of care as a broad framework for integrating ethics in undergraduate engineering. Such an approach would integrate ethics into the teaching of engineering in a way that accommodates the realities in which engineering operates, reflects the engineering ethos, and can address ethical considerations naturally. Care and pragmatism can contribute to addressing thorny problems– simple and complex, local and global- that engineers of today face. We suggest that these two approaches are more consonant with design approaches and hence should be familiar to engineering faculty. They have a natural fit with design thinking, so they mesh well with what engineers do. We believe that this framing can be used to weave ethics throughout engineering courses and enable students to become aware of the non-technical dimensions of engineering and navigate through their intricate links. This paper is a reflective proposal of how one could shape such an integration of ethics into engineering education.

Background and Motivation

The rules of professional practice in engineering until the early 1900's 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 1740's with the establishment of the first "civil" (as opposed to "military") engineering department in France in the École Polytechnique in 1794 [1], [2]. The American Society of Civil Engineers was founded in 1852 and is the oldest engineering society in the United States. The professional ethics of engineers was encoded in the codes of ethics of the professional societies.

Engineering ethics began to be taught and then required in undergraduate engineering curricula, starting in the late 1970's. This was the beginning of academic engineering ethics. It is when engineering ethics entered undergraduate curricula that engineering *faculty* looked for "founding principles" for engineering ethics rather than practice-based codes. The first theoretical frameworks developed by engineering faculty in collaboration with philosophers, looked to philosophical ethics for foundational 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, they also chose the Kantian principle of people as "ends rather than means". While textbooks mentioned other principles such as Rawls' theory of Justice, these two – utilitarianism and Kant's Imperative- translated as a version of the Golden Rule – remained the main basis. This was the case for example of the widely used textbook on engineering ethics [3]. The other pioneering textbook, by Martin and Schinzinger [4], framed engineering as "social experimentation", and chose three principles: Awareness (of the consequences of the engineering project); Autonomy (the engineer's right to make decisions); and Accountability (assuming responsibility for the work) as the three founding principles for engineering ethics.

Engineering ethics as articulated this way has challenges in being true to the working premise of the engineer. An engineer can follow Kant's categorical imperatives if she were a single moral actor with an obligation to one or a few individuals for whom she designs. But 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 translated as 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 [5]. He said that this is the most salient difference between engineering ethics and medical ethics. Medical ethics is premised on the one doctor to one patient type of obligation, under the tenets of patient autonomy, informed consent, beneficence, and non-maleficence. Thus, adapting from another established professional ethics was not readily possible.

An ethics specifically suited to the practice of engineering should reflect the ethos of engineering, encode the professional obligations and be aware of the realities of the world in which engineering is done and how its intended benefits and impacts play out. This means that an appreciation of decision-making at several levels, ranging from conception of a process or product to design and deployment, and use by diverse populations is a necessary part of engineering practice.

The Ethos of Engineering and Its Ethics

"Ethos signifies the "fundamental spiritual characteristics of a culture." The term "engineering ethos" or the "institutional ethos" thus captures the basic "spirit" of that endeavor or institution, the aspects that engineering or the institution takes for granted as defining its fundamental nature" [6]. Engineering is about working within external constraints and engineering practice is based on a way of thinking that is not applied science, but rather an evolving set of heuristics toward better design. Bulleit [7] calls this the "engineering way of thinking" (EWT). The EWT therefore articulates how the ethos of engineering operates in carrying out its objectives, and hence provides the background in which engineering ethics should function.

Engineering ethics is the study and definition of formal frameworks that determine the obligation and duty of engineering. A usable framework of engineering ethics should recognize and complement the EWT and include microethics, the engineer's individual responsibility and macroethics, which deals with the collective responsibility of the profession [8].

Rather than starting from philosophical principles and choosing the set on which to base engineering professional ethics, we 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 'knowing how', and knowing how requires thought about what to do, trying it, and then reassessing the thought based on the results of the trial; and awareness that at each of these stages, the engineer must make choices and decisions. Dewey [9] 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.

Such an ethics has to be *representational*, *functional,* and *aspirational*. Ethics is representational – it reflects and codifies time-honored yet current mores and ethos, the founding beliefs and practices of the society, and the profession it operates in. Kantian and utilitarian principles are representational. Kant's Principle is a loftier statement of the Golden Rule, a precept in all religions and social thinking that keep humans as a special species. So, it resonates with the thinking we have all been brought up with. 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. Thus, these principles are representational and in their bases, instrumental, in the society in which we operate.

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 on the individual and collective level, both with the engineers and the recipients and users of their work.

The above two are in the category of *preventive* ethics. Modern philosophers of technology like Hans Jonas [10], Manfred Stanley [11] and Charles Harris [12} have also challenged us to move toward an ethics that is *aspirational* because of the obligations brought about by the power, pervasiveness, and the potential to affect the global future. Harris et al. [12] states that "aspirational ethics has to do with using technology to promote human well-being", a pro-active rather than responsive role. Most recently, meta ethics and system ethics have been proposed as ways to include practical considerations in a complex system [13].

So far then, 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, from science and technology studies, and that crystallized in articulating engineering ethics in the context of the undergraduate education of the engineer.

Herkert [8] described these two lines in terms of micro- and macro- ethics: 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 microethical and macroethical approaches. (p. 106).

Teaching Engineering Ethics

One of the apparent problems is the way academic engineering ethics is taught now. It is mostly 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 for engineering ethics. Schmidt [14] has proposed an alternate paradigm for engineering ethics based on virtue ethics that addresses "what engineers do, how they do it, and why it matters". As he says, "...a virtue perspective affirms that ethics is fully integral to the profession." Stated even more concisely: "Your practice *is* your ethics!" However, most engineers do not work alone, with full autonomy. In the setting of an organization, for example, engineers may encounter practices being demanded that do not conform to their ethics.

When we think of teaching engineering ethics, good pedagogy and authenticity require that we articulate and approach the teaching as preparing students for behaviors consistent with the tenets, standards, and realities of the profession. As Weston [15] 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 [9]: "The indeterminate situation becomes problematic in the very process of being subjected to inquiry." (p. 107).

In the context of practice, pieces do not fit seamlessly without compromise. Frequently, the framing leads to a need to negotiate or decide between the business or policy decision based on economics, a utilitarian calculus, and a Kantian ideal of mutual respect for persons. Even in 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 relationships 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.

Societal ramifications and health and environmental impacts of rapid adoption and diffusion of technology in increasingly complex sociotechnical systems, unintended consequences often separated in space and time from the placement of the technology, possible compromise of human dignity, global distribution of the manufacture and placement of technology all demand an integrated system approach to engineering ethics. 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 to providing the entire context for the practice of ethical engineering.

Proposed approach –Pragmatism as the foundation

As elaborated by Bulleit [7, 16], the conditions described above means that engineers must make decisions that are "good enough", or "satisficing" [17], rather than optimal. They must develop heuristics, or rules of judgment based on experience. In the words of Koen

[18], “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.”* (Italics in original.) (p. 32)

Pragmatism is an American-born philosophy that originated in an effort to frame scientific knowledge as a current state of knowledge that may change with time, rather than as absolute truth. Founded by the scientist-mathematician-philosopher Charles Sanders Peirce in the late 19^{th} century and elaborated in the late19^{th} and early 20^{th} centuries primarily by him and psychologist-philosopher James, and later, philosopher- educator Dewey, pragmatism fits the engineering way of thinking and doing. The most accessible introduction to pragmatism is the reader compiled and edited by Menand [19], which includes many of the original essays on the subject by the pioneers.

Goldman [20] first suggested that Dewey’s pragmatism could very well be a “framework for a philosophy of engineering.” Bulleit [16] wrote, “The pragmatic movement is, in many ways, an approach to examining philosophical issues in a practical way. The same can be said for engineering as an approach to examining scientific and technological issues. If it works, use it.” (p. 14)

Pragmatism formally entered philosophy as Peirce’s attempts to examine how we form and hold to beliefs in his famous essay, “The Fixation of Belief” in which he sought a philosophy that “imitated the successful sciences, proceeding from tangible premises” with the reasoning being not a claim, but “a cable whose fibres may be ever so slender, provided they are sufficiently numerous and intimately connected” [21]. Later, Peirce [22] 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. (p. 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...” (p. 57). “The general leaning of the results is...toward common sense, toward anthropomorphism.” (p. 58). In this work, Peirce argues that inquiry is built within a context or situation, proceeding from prior experience. This is what engineering does. The basis of engineering on the state-of-the-art knowledge and the feedback in design are both attempts to do things better using what one learned from a previous version or experience, even in the face of uncertainty.

Having described the pragmatic method, Peirce explained what ethical considerations guided his principle of what he later came to call *pragmaticism*. In his essay, “How to Make our Ideas Clear” [23], he wrote, “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.” (p. 36). Thus, for Peirce, the value of an action is to be judged and communicated by the outcome.

Perhaps because of his language, and because Peirce, a scientist, was really aiming to solve problems of experimental design, Peirce’s work remained unnoticed until William

James took Peirce's work further and popularized it in his own way, despite Peirce's criticism and rejection of James' efforts. Peirce conceived pragmatism as a philosophy of ideas, of inquiry, logic, and scientific thinking. James, a medical doctor by training, a polymath, author of the first American text of Psychology in 1890, *The Principles of Psychology*, came at pragmatism as a psychology of ideas and necessary action. Thompson [24] 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..." (p. 202) This is similar to engineering where one *has to* act in the face of incomplete knowledge and externally imposed constraints. James [25] called his version "radical empiricism" in a "pluralistic universe." "The type of pluralism that represents what is best in our pragmatic tradition", writes Bernstein [26], "is an *engaged fallibilistic pluralism*." (p. 397). This is also true of the problem space of the engineer.

John Dewey is the third major founder of pragmatism. He was educated formally in philosophy. His reflections on democracy and political philosophy, on 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's version of pragmatism, stated in "The Need for a Recovery of Philosophy," was a philosophy to address "the problems of men" [27]. Dewey describes how values are defined as we look for ways to act, and that ethics is very much about action. Jafarinaimi, Nathan, and Hargraves [27] 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." (p. 95). Their statements and analysis are very much applicable to engineering as well.

Bernstein [26] (p. 385) characterizes the pragmatic ethos as "five interrelated substantive themes": anti-foundationalism, fallibilism, the social character of the self and a critical community of inquirers, contingency, and pluralism

- Anti-foundationalism: Knowledge does not rest on a fixed foundation, but is rather continually subject to revision.
- Fallibilism: We begin any inquiry with prejudgments and so philosophy is "interpretative, tentative, subject to correction." [p.387]
- Social character of the self and a critical community in inquiry: There is a need to have a critical community of inquirers. This implies a need for dialogue and coming to consensus in specific problems depending on the context. The increasing necessity for engineers to work in often interdisciplinary groups reflects this.
- Contingency and chance: Both of these are a reality. Dewey expounded on this. He wrote 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 (p 389). So, the pragmatists place emphasis on developing the complex of dispositions and critical habits that Dewey called "reflective intelligence." (p. 389), reminiscent of Schön's "reflective practice" [28].
- Plurality: Particularly advocated by Dewey, this means we 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 asks that we work on specific concrete problems, seeking solutions, it does not lay out steps to follow for a specific engineering project. We believe that working within the tenets of pragmatism, the ethic of care can help guide us to more specific steps for action. After the description of the Ethic of Care, we describe how these two can form the basis for teaching engineering ethics.

Ethic 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 [30] who found that a large number of people, especially women, do not identify with our moral responsibility being 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 "properties (virtues)" of an ethical person. There is a fundamental difference, however. Virtue ethics focuses especially on the states of character of individuals, whereas the ethics of care concerns itself with caring relations. 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 [31] states that: "... 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. Caring relations have primary value." (p. 19) Among the features both share, Groenhout [32] 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" (p. 174). This meshes with several properties of the pragmatic outlook we 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 their review of care and care ethics in engineering education literature, Campbell [33] writes that the earliest mention of care ethics in engineering was only in 1995, when electrical engineering professor G. Moriarty [34], 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 [35] elaborates on care not as a special *ethic*, but as an additional *virtue*, that of caring in a general way. Civil engineering educators Broome and Peirce [36] stressed "caring" as the motivation needed for engineers to become good, responsible, and even "heroic" in their practice. Kardon [37] 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 if this standard was seen 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 instruction, derived from case law, as the framework with an "emphasis on care, diligence and best judgment" (p.118).

In the early writing in engineering, 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 Joan Tronto [38], a political scientist, provides 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 [37] 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." (p. 40, Italics in original). In invoking this definition, Tronto specifically clarifies that this definition "is not restricted to human interaction with others." – to us 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 [39] emphasizes the role of repair as a ubiquitous and vital part of everyday caring.

Tronto [38] provides the background and introduction to the Ethic of Care most relevant to engineering and is the best starting point for an engineering educator to learn about the ethic of care. After a general introduction, she sets about showing that the idea of caring for others far removed had entered philosophy earlier through the thinking of the "Scottish sentimentalists" in the 18th century. 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 understanding of how to establish (solidarity) were no longer visible" because of increasing social and geographic distance in human life." (p. 36). The notions of sympathy – caring - arose in their works most famously in Adam Smith's *Theory of Moral Sentiments*, the precedent to his much more famous *Wealth of Nations.* 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 developed.

The ethic of care adapts well as a guiding framework for acting on complex problems. Tronto [39] 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" (p. 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." This is a central tenet for engineering ethics. Because of this, Pantazidou and Nair [6] used Joan Tronto's characterization of the phases of care to demonstrate the correspondence between practicing care and engineering practice. Jones, Michelfelder and Nair [41] 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. It is value-guided *practice*, not a system of values. 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 does, as ideally every engineering solution should, explicitly acknowledge and equally respect all aspects of addressing a need.

Joan Tronto [37] 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, which "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 [37] translates the four phases of care to the four elements of an ethic of care: *Attentiveness, Responsibility, Competence,* and *Responsiveness* (of the one being "cared-for"). Total care requires an attuned caregiver, who through commitment, learning and experience has an understanding of the process as well as the 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." (p.136) The elements of care, *Attentiveness* (recognizing and assessing need), *Responsibility* (assuming responsibility to address the need), *Competence* (needed to design a response) and *Responsiveness* (designing the response, and seeing if it addressed the need appropriately) are combined at the appropriate levels to provide a solution with integrity and ethics.

Two authors especially have carried the use of care ethics in concrete engineering venues. Kardon [42] came at it through elaborating how the legal system needed to interpret standard of care for engineering projects by analyzing several case studies of engineering failure and liability. Campbell [33] discusses the teaching of caring in the context of teaching engineering. We elaborate on this work below.

Empathy and Care

In his book *The Ethics of Care and Empathy*, care ethicist and philosopher Michael Slote [43] 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." (p. 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" for all these qualities and underlies caring. (p.4). While sympathy which 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 rather than merely associative. One projects oneself into another's situation. 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 [33] 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.” (p.20)

In normal engineering ethics, especially as taught, we focus mostly on the technical competence of the engineer. Care would say that technical competence is certainly an essential element, but only *one* of the elements of care in engineering. Every phase including problem “finding” and definition, and examining whether the technological solution is indeed the best, should be part of the design process, and indeed of the EWT. This is often impossible in organizational settings 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 et al., [45] explored how practicing engineers perceive empathy and care. 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, Miller and Sochacka [46] have proposed empathy as a teachable skill, based on a review of the teaching of empathy in social work. We return to some of these points below.

Integrated teaching of ethics with pragmatism and care – a proposal
So, the question we ask is: How does one use the ideas of pragmatism and the Ethic of Care to make ethics a part of engineering education rather than added as an extra dimension?

Pragmatism is an overall way of thinking, one that Dewey used effectively in spelling out how education and democracy work together, and for taking action in education. Dewey’s pragmatism produced concrete results such as the laboratory schools, which pioneered the progressive early education movement, and emphasizes teaching principles in context through practice.

Pragmatism and the ethic of care can be translated into engineering practice, and included in the way we teach engineering and science in the early part of the curriculum for example. Students should be made aware that science is dynamic, and that knowledge changes. We do not normally convey this when teaching science. The pragmatic way would say that rather than present the scientific background as a set of “proven”, unshakeable foundational canons, we make students aware of how scientists make decisions on what they observe and how. As the great teacher and physicist Richard Feynmann wrote, “We can imagine that this complicated array of moving things which constitutes "the world" is something like a great chess game being played by the gods, and we are observers of the game. We do not know what the rules of the game are; all we are allowed to do is to *watch* the playing. Of course, if we watch long enough, we may eventually catch on to a few of the rules. *The rules of the game* are what we mean by *fundamental physics*...” {47, p.2-1]. The pragmatic way would also say that we teach the students upfront how engineers use heuristics to decode what would work in a specific context. It is “If it works, use it.” We would then ask them to go further as they explore engineering decisions: they should reflect on what “works” means—work for whom? For what? This is a way to enter the realm of ethical decision making as a professional habit rather than overwhelm the student with ethical principles. It would be the pragmatic way – of practicing Bernstein’s pragmatic principles of anti- foundationalism, fallibilism, and engaging them as a “critical community of inquirers”.

Some of the pedagogical methods that can encourage this broader thinking in teaching the sciences and engineering are inclusion of stories of discoveries and inventions as readings, and having students draw concept maps of the historic progression of ideas in the art and science of engineering. Students in the first two years often resist this “non-scientific” content in their technical courses. But they come to appreciate the larger picture as it connects with their technical and scientific understanding of the world. Including discussions of the EWT as part of projects in early courses facilitates building their mental model of engineering.

As the students’ worldview of engineering develops, the latter two of the Bernstein pragmatic principles – the role of contingency and chance, and plurality can emerge. The “allowing” of contextual dimensions into engineering classes can develop these sensibilities in students – sensibilities that they probably had as children, but was “taught out” of them in science and technology classes.

An “envelope” of pragmatism can thus be incorporated into the students’ learning in the early years of the engineering curriculum. The care ethic and its phases of attentiveness, responsibility, competence and responsiveness can then provide the skills needed to practice design – the central activity of engineering. Pantazidou and Nair [6] described how Tronto’s phases of care- attentiveness, responsibility, competence, and responsiveness- map to the phases of design and engineering problem solving - identification of need (problem definition in context), conceptualization (selecting method), feasibility analysis and production (solution, verification, practice). This process then yields a design with the integrity of care, integrating the four phases to an appropriate whole.

Kardon [42] has examined the whole spectrum of engineering activity and concludes that all the care elements “come to bear in each phase and activity”, as “engineering encompasses much more than design”. In this work, Kardon examined how the care element – the “engineer’s standard of care”-- failed in several cases. He sums up,

“In fact, there is not a one-to-one correlation between the elements of care and the phases of engineering services; all the elements come to bear in each phase and activity. ... in designing, but also in planning, manufacturing, constructing, operating, maintaining, modifying adapting, repairing, dismantling, and disposing of engineering facilities.” (p. 22) Making students aware of this early in the curriculum can begin the work of educating ethical engineers.

Two works have explored in some depth how to integrate care and empathy in engineering ethics education. We believe both these works offer a range of possibilities for problem choice for design projects or discussions that introduce ethical issues naturally into the teaching of engineering. Campbell [33] asks, "How can engineering students learn to care? How can engineering faculty learn to care?" and points out that the earlier works lack the essential altruistic and interpersonal nature of care. One of the primary ways in which he answers this is to provide students opportunities through humanitarian engineering, involving community projects and including a full assessment of the needs and the resources of the community as well as its wishes. In this he calls for empathic care, which gives respect, and autonomy to the community the engineer is trying to work for. Hess et al. [44] discuss "empathic perspective-taking" and ethical decision-making in detail. Based on studies of the role of empathy in ethical reasoning in other fields, they arrive at "empathic perspective-taking" as the cognitive form of empathy. They discuss the ideas of acceptable risks in engineering design, social justice and socio-technical design and sustainability and environmental engineering as routes to teaching engineering ethics embedded within the curriculum.

It is worth noting that the earliest engineering ethics textbook by Martin and Schinzinger [4] while not discussing care and pragmatism explicitly, do raise several of the above elements as components of engineering ethics. Their four principles are: (1) understanding of "engineering as social experimentation", requiring "imaginative forecasting of possible bad side effects", and careful monitoring of projects; (2) awareness of all aspects along with respect for people's rights to give informed consent; (3) autonomy of the engineer and (4) accountability, so that engineers act as responsible agents and "accept accountability for one's conduct" (p. 103). Educating engineers to act this way would lead to fulfilling the requirements of care. But, we believe the framing of engineering design and projects along the phases of care gives a more usable framework.

However, articulating the framework of pragmatism, care ethic and empathic perspective-taking make explicit the affective and cognitive dimensions of ethical behavior of the engineer as a member of a professional community. Introducing these early in the curriculum, and embedding questions and examples of ethical behavior opportunistically into the "technical" courses of the major can lead to the students integrating ethical behavior, and macro- and microethics as part of being a professional engineer. Having the EWT/ pragmatism framework and the steps of care in their mental models can enable discussion of such instances naturally. In addition, students begin to understand that in making choices in engineering work involves implicit or explicit decisions that have consequences. Hess et al. [44] point out how, for example, an empathic perspective-taking may have led to a different decision about the launch of the space shuttle Challenger.

Incorporating these elements into early engineering education also begins to make topics such as risk assessment, decision-making, and environmental life cycle analysis become an integral part of doing engineering thinking rather than as add-ons or after-thoughts after the technical decisions are made. This could begin to change the ethos of engineering in the mind of the student, and ultimately in the practice of everyday engineering. In the "capstone" type courses such as senior design and other applied courses, or in a dedicated engineering ethics course, students can be introduced to the meaning of a profession and professional ethics and the deeper philosophical meanings of ethics. This approach would then have the effect of the students seeing engineering ethics as an inherent part of the engineering *practice* and *engineering way of thinking* as they have been taught all along, rather than as an artificially introduced component of engineering education.

We conclude this reflection with a brief proposal for an overall pathway for such an approach in a typical four-engineering curriculum, using an idea of three general (overlapping) phases of the four-year undergraduate curriculum: Exploration, Focus and Expansion [48,49].

In the Exploration Phase (first three semesters), students explore the background for ethics as related to engineering, in the form of the Engineer's Way of Thinking discussed above. This has the added benefit of motivating the students as they think of how their courses prepare them for the EWT. The idea of care in relation to engineering can be organically introduced here in the context of the engineering content of the first year introductory course, as can the ideas of professional responsibility. Thus the student is engaged in "meaning-making" as advised by Novak [50] as the students are "dynamically building connections between their existing knowledge and the curriculum content" in the framework of Slotta and Linn [51]. This stage is also useful in engaging students in the preliminary discussions of engineering decision-making and consequences. There are powerful ethics cases such as the 59-story crisis and the Hyatt Regency Walkway collapse that can engage the students.

The Focus phase (semester 3 to 6) is the opportunity to incorporate examples of ethics issues in the main engineering courses as the occasion allows. The ideas of micro- and macro-ethics, stages of care and of pragmatism in the form of fallibility (approximations necessary and implications), evolving knowledge, uncertainty and risk and the need for lifelong learning, communities of inquiry and the need for engaging the public served, can all find place here with thoughtful planning. Doing this in the engineering courses models for the student the integrative thinking needed to be an engineering professional. This is the phase for which some intensive engagement of engineering faculty through ongoing faculty development and provision of material is needed, perhaps the most challenging part of our proposal.

The Expansion phase (semester 6-8) is then used to integrate the learning in readiness for a reflective, ethical professional life. This is probably the best place to have a dedicated engineering ethics course that revisits the topics in the earlier phases, integrates the learning through case studies and role-playing exercises, and provides the theoretical underpinnings. Through the earlier phases, the student is prepared to understand the level of theoretical abstraction in ideas of pragmatism and able to think of examples in their senior design courses about the application of these theories.

We realize that this proposal requires full engagement on the part of the engineering faculty, but the gradual phasing of ethics in the curriculum can give the faculty the opportunity to learn, grow, and feel comfortable with the concepts gradually. Their students in turn see ethical role models in the faculty and emerge as socially responsible engineers.

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