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In this thesis, I conduct an analysis of paradigmatic background assumptions deployed in engineering decision-making processes, in order to understand how these assumptions, operating tacitly and in tension with each other, contribute to decisions that are ethically less effective and less substantial than they would otherwise be. I do so by exploring the role of background assumptions in evidential reasoning processes, the operational features of paradigmatic background assumptions, and the idea that engineering is an inherently moral activity. I argue that current attempts to resolve the tension introduced by paradigmatic background assumptions are ineffective, and if engineering communities wish to maintain legitimacy as material problem-solvers of our shared world, then decision-making processes should be able to adjudicate between paradigmatic background assumptions. I argue that the four features of objective scientific communities identified by Helen Longino – public standards, venues for criticism, critical uptake, and tempered equality – provide a useful framework for engineering communities to begin discussing, revising, rejecting, and embracing particular paradigmatic background assumptions. This process would lead to engineering decisions that have the potential to be more ethically effective and substantial. I conclude by outlining potential objections to my analysis and raising questions for further research.

Toward a More Ethical Engineering: Four Habits of Highly Ethical Engineering Practice

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Masayuki Luke Sugie

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APPROVED:

Sharyn Clough, representing Applied Ethics

Head of the Department of Philosophy

Dean of the Graduate School

I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

Masayuki Luke Sugie, Author

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Preface

As an undergraduate studying Chemical Engineering at Oregon State University, I was expected to excel in the technical subject matter of my chosen field: chemical reactions, thermodynamics, reactor systems, process analysis, and a variety of other math- and science-based topics. However, upon approaching graduation I discovered an unstated, unacknowledged and unexamined link between the core of technical problem-solving in my field and the ethical questions of how engineering decisions can, should, and undoubtedly will affect our lives.

What is the proper role of ethics in engineering decisions? How do we account for decisions that affect future generations or unintended populations? What is the proper role of social movements in engineering? An education adequate in technical subjects does not automatically bestow competence in answering these difficult ethical questions. However, the history of engineering in the United States demonstrates that ethical questions should have been as important, or more important, than questions about particular technical considerations.

A critical examination of the role of ethics in engineering communities was rarely brought into coursework by my instructors. In a field heading toward increasing specialization this can be understood as a pragmatic move; a rigid, technically-oriented class schedule will make it difficult to include ethical aspects of engineering, including subjects such as the philosophy of technology or engineering ethics. The consequence, as I explain further in chapter 1, is that when ethics is discussed at all, it is presented as a set of conflicting rules focused on the action of individual engineers. While social processes form the bulk of engineering decision-making, ethical responsibility is still presented as an individual burden.

The inadequacy of education about engineering ethics is not unique to OSU. Faculty in engineering departments, engineering practitioners, and organizations of engineering professionals across the United States struggle with questions about the proper role of ethics in engineering. Broadly, society struggles with the ethics of engineering each time failures of engineering, and the highly public disasters that may follow, are brought to light. Furthermore, the demand for engineering practices that are responsive to broader social movements, such as sustainability, environmental justice, poverty eradication, and water quality and access, will, by necessity, involve many different groups and engineering communities. If engineers desire to be legitimate material problem-solvers in our shared world, engineers ought to strive to produce accounts of engineering decision-making that are ethically effective and substantial. By effective and substantial, I mean that engineering decision-making ought to be able to ethically resolve the problem under consideration, and do so without introducing additional ethical problems. They must also develop an understanding of how ethics interacts with decision-making processes in engineering, and the background assumptions influencing such processes.

A sociological analysis of the practice of engineering in the U.S. supports the idea that engineering decision-making processes are influenced by a variety of assumptions that may or may not be stated or made salient to engineers. These implicitly held assumptions appear in problem generation, methodological analysis, and resolution. Further, these assumptions, which are informed by both facts and values, comprise individual and collective worldviews held by engineers.

Engineers can and do adopt implicitly held assumptions as they engage in engineering decision-making. Some might argue that this analysis places a burden on engineering communities that is more apropos to the ethics of business and/or politics. I argue that an analysis of implicitly held assumptions belongs within the scope of engineering communities for several reasons. Suppose there are two groups of engineers who hold substantively different viewpoints about the role of ethics in engineering practice, and encounter conflicts about particular practices of ethics in engineering when talking to each other. Assumptions influencing the ethical decision-making processes of both engineers may be completely or partially unavailable for critical scrutiny, and will even mask their own influence on ethical decision-making. Both engineers will likely adopt ethically less-effective and less-substantial decision-making processes because of the unacknowledged influence of assumptions on their decision-making. Further, without a sufficiently critical understanding of how one should act according to coherent ethical principles, engineers may unknowingly support and even foster the arbitrarily imposed hierarchies that maintain and promote systems of power and privilege under which all involved are less effective in providing well reasoned, ethically substantial and effective outcomes.

Contained within the work of many feminist philosophers of science is a demonstration that what have typically been called “non-cognitive values” or “contextual values” routinely influence scientific practice. Insofar as these values function implicitly, they can often have negative effects on scientific research. As practitioners of applied science, engineers are as likely as scientists to use implicitly held background assumptions that affect decision-making processes. And as a practice rooted in mediating disparate and often conflicting features of the material world, we expect background assumptions in engineering to affect many more people than decision-making processes in sites of less applied scientific research such as physics or mathematics.

I argue that Helen Longino's naturalized empiricism is particularly useful for addressing implicitly held paradigmatic assumptions in engineering as much as in science. Her naturalized empiricism distinguishes constitutive and contextual values that operate within scientific practice and influence it significantly. Constitutive values form what is called the “cognitive” foundation of science, and include values of accuracy, simplicity, truth, predictability, and breadth (Longino 4, Potter 99). These values form the boundaries of acceptable scientific practice. Contextual values are “non-cognitive” values that express how things *ought to be* in the context of scientific practice, and encompass a variety of political goods, psychological states, and other socially contingent beliefs. It is easy to demonstrate that the core of engineering encompasses similar constitutive values as science, but much more difficult to determine where and how contextual values gain more or less legitimacy or relevance for engineers and engineering decision-making processes.

Longino's development of naturalized empiricism, along with sociological examinations of the practice of engineering, provide a starting point to move the discussion of engineering ethics from an individually engaged question of “What are the attributes of an ethical engineer?” toward a socially engaged question of “What are the attributes of ethical engineering decision-making processes?" By shifting this discussion, engineers will gain the ability to acknowledge how contextual values ethically affect engineering decision-making processes, and provides opportunities to critically analyze contextual values using *explicitly* local, contextual and social process. Finally, this shift calls for an active exploration of more perspectives than currently accounted for in engineering decision-making processes, necessitating broader decision-making communities who can produce outcomes that are ethically effective and substantial.

My thesis is an attempt to answer the following questions: What are some of the background assumptions, explicit or tacit, that create and inform the ethical standpoints of engineers? Are there local, contextual forms of engineering ethical decision-making that may lead to more ethically substantial and effective outcomes? By beginning to answer these questions, I hope to contribute to an engineering decision-making process that is ethically substantial and effective at resolving how engineers engage with our collective world and solve material problems.

Toward a More Ethical Engineering: Four Habits of Highly Ethical Engineering Practice

Chapter 1 – Introduction to the Role of Background Assumptions

I begin this chapter by exploring the role of implicit background assumptions in connecting evidence to hypothesis, in order to demonstrate how causal schemes are presented and defended using background assumptions. Next, I examine how paradigmatic background assumptions are deployed, defended, revised and rejected, and present a list of several background assumptions that influence engineering decision-making processes. Finally, I demonstrate that engineering is an inherently moral activity and advocate for the examination of background assumptions and their roles in creating ethically substantial and effective solutions when deployed in engineering decision-making processes, which I describe in the next chapter.

Functions of Background Assumptions

While I have so far spoken critically of background assumptions, it is important to acknowledge that background assumptions systematize and order our world, and provide the necessary framework to anticipate the future behavior of features of our world taken to occur regularly. Longino describes background beliefs or assumptions as an enabling condition of the reasoning process (42). As such, assumptions establish evidential relationships between an observation and a hypothesis, such that we are inclined to understand observation ***x*** as evidence for hypothesis ***h*** because a background assumption makes a link between ***x*** and ***h*** (Longino, 43-44). Background assumptions are analogous to the role of background conditions in causal interactions, providing enabling conditions for a causal scheme to be developed (Longino 44). For example, imagine a person walking down a street and noticing an MP3 music player lying on the road. “Ah!” the person might exclaim, “I've found an MP3 player that someone has lost!” When asked why the MP3 player beside the road is understood as a lost object, the person may say it is unlikely for an MP3 player, as a valuable object, to be purposefully unattended in the road. The statement “valuable objects are not likely to be purposefully unattended” functions as a background assumption, permitting a causal scheme to be developed between an observation (“an unattended MP3 player in the road”) serving as evidence in support of a hypothesis (“this MP3 player was not purposefully left here”). This person may also gather additional observations as evidence in support of their hypothesis, such as how the player appears to have been dropped, etched markings on the backplate, and other observations of the MP3 player that provide evidence to support the hypothesis by using a background assumption that identifies an MP3 player as a valuable object. Background assumptions function as inferences permitting a causal scheme to be developed and defended from other possible causal schemes (Longino 44).

Furthermore, the route used to develop or defend a causal scheme that links an observation as evidence in support of a hypothesis will vary according to background assumptions. Variations in background assumptions lead to variations in, and challenges toward, how and if observation counts as evidence in support of a hypothesis (Longino 45). Thus, returning to the previous example, if another person held a background assumption that MP3 players are cheap and disposable, the likelihood of this person understanding the MP3 player in the road as a lost item is less likely. Instead, this person might understand the MP3 player as a piece of discarded trash someone threw on the ground.

Background assumptions also have the ability to “both facilitate and constrain reasoning from one category of phenomena to another” (Longino 59). Once a person has concluded that there is only one or only a few hypotheses about why the MP3 player is on the road, how this person interprets observations as evidence in support of a hypothesis will depend heavily on the hypothesis itself. If the person is gathering observations as evidence that the MP3 player is lost, they may look at the specific location where it was found, its engraving or identifying features, functionality, apparent age, etc. The person gathering observations as evidence that the MP3 player was purposely discarded may not need further observations beyond the initial observation that the object in the road is an MP3 player. Each person may also determine that there are equal amounts of observations giving evidence to both hypotheses, or that the same observation may give evidence that supports multiple, competing hypotheses (e.g. the player has damage consistent with being dropped, but there is no way to determine if damage was on purpose or accident). This leads to a problem: what criteria should a person use to adjudicate between two potentially equally supported hypotheses that may be mutually exclusive to each other, not to mention the infinite alternate explanations possible for any particular observation?

Adjudication between competing hypotheses may be relatively unimportant in this example or most examples because there may be only one hypothesis, or a few hypotheses, under serious consideration at any moment. Unfortunately, as I describe further in chapter 3, *theory is always underdetermined by evidence,* and reasons for ruling out connections between particular evidence and hypotheses cannot (and do not) rely on logic alone. For now it is sufficient to acknowledge that this problem exists, and that the choice of evidential relationships is not as clear as may be believed.

Adjudication between competing hypotheses is particularly important when the potential actions invited by an evidential relationship involve ethical decisions. Ethics is broadly concerned with how persons *should* or *ought to* treat each other, and ethical decisions reinforce particular notions of how we ought to treat each other. In the example of the MP3 player in the road, the person operating under an assumption that the MP3 player was lost may make a report to the police, or at least make a good-faith effort to find the owner. The person who assumes that the MP3 player was purposefully discarded may take the MP3 player or walk past it without attempting to find the owner. Depending on the background assumption used to develop a causal scheme, different ideas about the moral and legal responsibilities of the person walking past the MP3 player may be articulated. Accepting one causal scheme as a preferred interpretation of events may lead individuals to act in what is later determined to be an unethical or immoral manner. If we wish to act in an ethical way, determining how to adjudicate between competing background assumptions will be necessary.

Paradigmatic Background Assumptions

Returning to Longino's definition of background assumptions, I use the term *paradigmatic background assumptions* to refer to statements taking the form of systematic, structural, and ordering presuppositions. While paradigmatic background assumptions are sometimes explicitly adopted, their continued use is mostly implicit, a phenomenon I explore later in this chapter. By providing a framework of evidential relations paradigmatic background assumptions provide insight, perspective, and access to additional information when deployed, operating identically to Longino's concept of background beliefs and assumptions. To add to Longino, I argue that paradigmatic background assumptions are used because an individual presumes that these presuppositions are empirically accurate correlations with lived experience. For example, classical mechanics is not explanatory of all observable phenomena of a physical system, yet most engineers will frame their understanding of their world within the constraints of classical mechanics. Engineers can and do, of course, use other models to describe physical systems, and understand classical mechanics as an imperfect explanatory model of all observable phenomena. Despite the limitations of classical mechanics, engineers continue to use it because it aligns “closely enough” with the world for most engineering problems and solutions.

This is not to say that engineers are incapable of rejecting or revising paradigmatic background assumptions, or that they necessarily ignore observations countering a particular theory or assumption. Similar to Longino's conception of background beliefs and assumptions, evidential relations are “not autonomous or eternal truths” that exist independently of individuals, “but are necessarily constituted in the context in which evidence is assessed” (59). Furthermore, while Longino occasionally uses “belief” and “assumption” interchangeably, she describes belief as “explicitly adopted tenets” and assumptions as a necessity to evidential reasoning that “is not explicitly acknowledged” (59). Because of difficulties in demarcating when a statement is explicitly or not explicitly adopted, I collapse terms such as “belief,” “cognitive values,” “non-cognitive values,” “ideals,” “socially contingent belief,” “fact,” and other terms demarcating particular forms or distinctions of beliefs and assumptions into the term “paradigmatic background assumption.”

Paradigmatic background assumptions often cross commonly held notions of what constitutes a “fact” and what constitutes a “value.” Considering the energy and attention by philosophers of science and epistemologists to establish criteria for differentiating facts and values, some might argue against my making use of the term “paradigmatic background assumptions“ because I conflate facts with values and both into a unified operational structure. Here I join forces with fact/value holists such as W.V. Quine, Lynn Hankinson Nelson, Donald Davidson, Sharyn Clough, and others who argue that all statements of meaning, whether factual or evaluative, have cognitive, i.e. empirical, content, operating in a “web of belief” where all our statements are co-supported more or less robustly (Clough 2003, Potter 32-57). This holistic picture does not make it impossible to identify true (or more-true, or less-true) statements; indeed, all statements on this account have the potential to be revised, update, rejected or modified in light of new evidence (Clough 107). An engineer may reject classical mechanics as a physical model of the world if her experience with a particular problem demonstrates a need for a different physical model to serve as a structural foundation for problem-solving, just as an engineer may reject previously held racist paradigmatic background assumptions if his lived experience demonstrates a need for a new assumption during the assessment of other's abilities and accomplishments (Clough and Loges 87).

Paradigmatic Background Assumptions in Engineering

In this thesis, “engineers” refers to those people who have completed formal

U.S. engineering education and currently practice in the U.S. "Engineering communities" refer to groups of engineers who can be ascribed a similar set of background assumptions taught implicitly or explicitly during engineering education and practice. Implicitly taught background assumptions are taken up by an engineer without being stated or acknowledged, while explicitly taught background assumptions are those that are stated and acknowledged, and are typically found in guiding documents (i.e. codes of ethics), in coursework, or in other documents related to engineering and engineering communities.

A review of some historical, sociological and pedagogical literature on engineers and engineering communities (see Rae and Volti, Humphreys, Verbeek, Swierstra and Jelsma) makes available a number of paradigmatic background assumptions. I list six here, providing a description and analysis of their content:

1. **Engineering is a morally positive endeavor. At the very least it is morally neutral.** Technology designed and created by engineers is at worst a neutral tool, shaped and determined by the individuals employing it, and at best a morally positive force of change. This assumption is primarily implicitly promoted, as seen in "Code of Ethics" documents promulgated by professional engineering societies, which I analyze in Chapter 2. Briefly, these codes help legitimize engineering as a profession and necessarily involved describing the relation of the engineering profession to broader society. As a result, many of these codes contain appeals for engineers to work for the sake of the public, with paramount goals of improving or upholding human welfare and safety (Lozano 247, "AIChE Codes of Ethics," "NSPE Code of Ethics for

Engineers”).

2. **Engineering is empirically adequate or empirically based.** As a field of applied science engineering is rooted in evidence-driven processes, similar to those at sites of scientific study. Therefore engineering decisions rely on scientific concepts and are adjudicated by referring to the same empirical processes operating in science. Ethical considerations affecting engineering are non-empirical, i.e. these decisions are unable to be adjudicated with empirical processes. While ethical considerations influence engineering, they are peripheral to an empirical process central to engineering problem-solving. This assumption requires a sharp distinction between facts and values, and the subordination of values to facts (Kleinman 4). This assumption also presumes that secondary, non-empirical processes affecting engineering rely on “common sense,” i.e. morality based on common standards of behavior and conduct (Humphreys 32-33).

3. **The profession of engineering, and the products of engineering, is accessible to all individuals, regardless of social, cultural and personal characteristics.** Historically, the core problem-solving processes in engineering were viewed as primarily the domain of principles of math and science. As math and science were viewed as universally accessible to most men, engineering was therefore open to any man from most any background, provided he could demonstrate competence in these two subjects. Today math and science are viewed as mostly accessible to women as well, and a historical analysis of engineers demonstrates the upward social mobility of the men (and

few women) who became engineers, and many engineering fields are composed of people who originated in blue-collar or working-class families (Rae and Volti 200-203).

4. **Engineering is a practice of solving material problems within the context of corporate cultures.** The demands of creating a complex physical infrastructure during the late industrial revolution led to an increasing corporatizing of engineering, as the need for large, organized teams of engineers became necessary (Rae and Volti 119, Schinzinger and Martin 24). By 1986 it was estimated that between thirty and forty percent of engineers were employed by organizations of 5,000 employees or more (Rae and Volti 140).

5. **Engineering as practiced in the "Western" or "first" world is the model for engineering elsewhere or everywhere.** The empirical and scientific roots of engineering are heavily associated with the Western world and Western methods of knowledge accumulation (Dusek 156). Historical examples of technology importation, and the continued call for non-Western countries to adopt Western technologies, demonstrate how pervasive this particular paradigmatic assumption is (Dusek 160-161).

6. **Technology and the products of engineering are the principle way to improve the human condition**. Technological positivism of the Enlightenment period ascribed a superior rationality to empirical processes as a way of understanding the world, and therefore the acquisition of scientific

knowledge and the application of technology are the solutions to material problems (Scharff and Dusek 83-85). The best method to achieve the goals of any progressive program is through technology (Kleinman 4-5). Engineers, as the producers and designers of technology, are significant contributors to the improvement of human welfare and progress.

The unstated and unacknowledged background assumptions I presented above cover many different political goods, cultural attitudes and psychological commitments to particular conceptions of technology and the role of engineering in society. It is important to restate that the list of paradigmatic background assumptions I developed above is not a universal or exhaustive list of paradigmatic background assumptions applicable to all engineering communities, but limited in scope to engineers and engineering communities within the U.S. I call the collection of paradigmatic background assumptions above the "ideology" an engineer will use to navigate decision-making processes within engineering. By "ideology," I refer to Bjørn Ramberg's definition of ideology as "a systematic misrepresentation, distortion or concealment of social reality" (639). Individual assumptions on the list above may produce severe tension by being both internally incoherent and incoherent with other assumptions, yet all are capable of being used by engineers more or less continually because their operation remains on the edge of awareness, a feature of assumptions I explain shortly.

Ideology is a dialectical process in that it conditions the material world to conform to specific social structures, and alters our understanding of the world by presenting socially contingent features as unalterable or essential features of our world

(Potter 135). Thus the ideology of an engineer misrepresents, distorts, and conceals social reality by legitimating a particular worldview, in the process legitimating particular social structures to reflect such a worldview (Ramberg 638).

For example, imagine an engineer who thinks that Western engineering is, or should be, the paragon model for engineering elsewhere or everywhere. As evidence she may examine the physically difficult engineering projects and infrastructure Western countries are responsible for creating and maintaining, and wonder why non-Western countries do not adopt ideas of Western engineering. When technology fails in a non-Western country, or when preventative technology is absent – for instance, the lack of a tsunami warning system in the Indian Ocean before the Great Sumatra-Andaman earthquake of 2004 – her view of Western engineering as superior appears supported. “If only the affected countries had adopted our engineering to a greater extent,” she might remark, “many deaths might have been prevented.” At the same time, she may dismiss similar instances of technological failure in Western countries – for example, the devastation of Hurricane Andrew in 1992 and Hurricane Katrina in 2005. These catastrophes are not viewed as failures of Western engineering, but as failures of those who make and enforce public policy. Her ideology presupposes a particular interpretations of the world and reinforces her notion that Western engineering is superior.

Like all assumptions, those listed above operate in particular ways to ensure that they remain on the edge of awareness of engineering communities, and yet are also able to stand in tension and contradiction with one another and other assumptions in engineering. First, assumptions are almost never tested during engineering problem solving. Regardless of whether or not an assumption *should* be tested as less true or incompatible with other assumptions, it is seldom tested in engineering problem solving. Assumptions are considered “settled,” resolved in history, or agreed upon to a degree not warranting further study (Heywood 53-88). Second, assumptions are taken for granted in that they appear to be the product of self-evidential statements. For example, understanding the profession and products of engineering as morally neutral or morally positive is considered self-evident by “obvious” criteria such as an increased life span or productive power of those countries with a heavy investment in technology. Third, assumptions rely on social systems and cultures that encourage the uptake and reinforcement of particular assumptions (Prentice 534-537). In total, these features of assumptions presuppose that a critical examination of assumptions in engineering decision-making are considered distractions and subordinate to more important empirical-based problem solutions. Engineering communities support this viewpoint by providing no reward, financial or otherwise, for the critical examination of how assumptions influencing engineering decision-making do or do not contribute ethically substantial and effective solutions.

Individually, any of the paradigmatic background assumptions in engineering I listed above may give rise to specific, identifiable actions among engineers that may permit critical scrutiny. But the total cumulative effects of these paradigmatic background assumptions are invisible within engineering, even from those who gain explicit access to these assumptions. By being present in decision-making processes yet unavailable for critical scrutiny, considerable tension is introduced to engineering decision-making processes by the aggregate affects of such paradigmatic background assumptions. For example, imagine an engineer who dismisses sociological analysis of the development, structure and functioning of engineering cultures by assuming engineering is empirically adequate or empirically based. He might assume that engineering is morally neutral or morally positive, yet also assume that successful problem resolutions in engineering do (or *should*) rely primarily on empirical criteria. For him, morality and ethics are conceptually separate from the world of empirical data. Ethical considerations are present, but irrelevant to the primary purpose of engineering. The unintended effects of a morally positive viewpoint of engineering and technology will become unimportant to successful engineering solutions, and thus become unavailable for critical examination. The decision-making processes he will advocate for, and engage with, will be unlikely to address the paradigmatic background assumptions affecting his decisions.

Engineering as an Inherently Moral Activity

Two analyses of engineering ethics demonstrate that marginalizing the analysis of the paradigmatic background assumptions I outlined above contributes to ineffective or insubstantial engineering problem resolutions. The first analysis is from Peter-Paul Verbeek's phenomenological study of the forms of mediation produced by technological artifacts, and establishes engineering as an inherently moral activity that materializes, i.e. brings into physical presence, particular perceptions and possible actions within the world ("Materializing Morality" 368). The second analysis relies on sociological studies of engineering and science demonstrating the complex, social nature of engineering (Verbeek, Swierstra and Jelsma, Rae and Volti). These contextual problem-resolution processes are replete with interactions of ethics and moral frameworks, further demonstrating that paradigmatic background assumptions, marginalized by engineering's commitment to empiricism, are significant in engineering decision-making processes.

According to Verbeek, technological mediation involves two relations of mediation, corresponding to how a technology mediates between human perception and human action. The mediation of perception, clarified by Don Idhe and used in Verbeek, is invoked when technology transforms an individuals “sensory relationship with reality” (“Materializing Morality” 365). This form of mediation can be embodied and transform our direct perception, for example as with eyeglasses, or this mediation may involve a hermeneutical relation that requires interpretation to understand, for example as with reading a thermometer (Verbeek, “Materializing Morality” 365). The technological mediation of perception necessarily involves an amplification or reduction of particular aspects of an individuals perception, and the process of interpreting aspects of amplification and reduction is a socially contingent and contextual feature of technology (Verbeek, “Materializing Morality” 366). Verbeek aptly demonstrates the mediation of perception with medical imaging technology:

> Such technologies make visible parts of the human body, or of a living fetus in the womb, that cannot be seen without them. But the specific way... these technologies represent what they “see” helps shape how the body or a fetus is perceived and interpreted and what decisions are made. In this way, technologies fundamentally shape people's experience of disease, pregnancy, or their unborn children. (“Materializing Morality” 366).

The technological mediation of perception can influence moral reasoning processes by allowing or disallowing information that may not have been present otherwise, and/or by influencing the ways an individual who is using moral reasoning skills literally “sees” the world.

The mediation of action relies on an assumption that technology deploys particular “scripts” on actants, an idea introduced by sociologists like Latour and Akrich during their phenomenological studies of technology (Verbeek, “Materializing Morality”). Scripts are specific actions that technology compels a person to do, and can be intentionally or unintentionally materialized (Verbeek, “Materializing Morality” 366). The scripts deployed by technology invite or inhibit particular actions a person may undertake (Verbeek, “Materializing Morality” 367). This should not be confused with claiming that technology exhibits a form of agency; rather, technology is inviting or inhibiting actions based upon the “scripts” and “programs of action” inscribed by their designers. For the purposes of my thesis, I join Latour in claiming that technology functions as “actants” and not “agents,” in that technology acts out particular scripts within networks of relations between humans and non-humans (Verbeek, “What Things Do” 148-152).

As with the mediation of perception, the mediation of action is also socially contingent. Verbeek uses the history of the telephone as an illustrative example of the contextual mediation of action. The telephone, initially designed as a device to aid communication with hard-of-hearing people, began to develop a role in maintaining social ties across broader geographical distances than ever before (Verbeek, “Materializing Morality” 367). The telephone thus began inviting individuals to maintain geographically distant social relationships, and whose eventual widespread adoption began inhibiting or discouraging relationships with individuals who did not have access to a telephone.

Technological mediation involves two relations of mediation, inviting or inhibiting perceptions of, and potential actions to be undertaken in, our shared world. The design of all technology is an “inherently moral activity” in that it materializes morality for others (“Materializing Morality”368). Questions of how technology is designed, including questions about by whom and for whom technology is designed, are essentially moral questions. Engineers, as mediators of the material world and designers of technology, will therefore have a responsibility to be able to substantially and effectively resolve ethical questions occurring during the development of technology. As a field concerned with the relationship between the practice of engineering and the broader world, engineering ethics would benefit in understanding relationships between how paradigmatic background assumptions and engineering decision-making work together to mediate our material world.

The second analysis demonstrating the importance of treating these paradigmatic background assumptions as problematic is by way of sociological studies of engineering and science demonstrating the contextual social and moral frameworks operating within engineering problem-resolution processes. As we will see, the introduction and interaction of social and moral frameworks in these processes are influenced by paradigmatic background assumptions.

As I mentioned earlier, the majority of engineers are overwhelmingly employed by corporations or government entities. Decision-making processes in these contexts will necessarily interact with corporate or governmental decision-making processes, and both will operate within an ethical framework of legal responsibilities and professional standards. Typical examples of ethical dilemmas faced by engineers involve cases of whistle-blowing against employers or clients, i.e. situations where an engineer conveys an appeal for a decision to be reexamined by external entities. Inevitably these case studies of engineers in corporate or governmental settings involve individual or small groups of engineers who “stand up” to larger corporate or governmental structures and hierarchies (Rae and Volti 210-215, Schinzinger and Martin 167-181). Any discussion of the ethical responsibilities of engineers will necessarily involve workplace responsibilities and worker rights, in addition to the complex legal and professional commitments each engineer holds (Schinzinger and Martin 143-184).

Taken together, the phenomenological and sociological analysis of engineering and engineering cultures demonstrate that in addition to materializing morality for others, engineering cultures rely on a variety of socially-driven decision-making processes to solve material problems. The paradigmatic background assumptions I listed above, operating together, influence engineering decision-making and narrow what possible problems and solutions are analyzed and acted upon. Furthermore, these assumptions mask their influence on engineering decision-making processes, by definition are unstated and unacknowledged among engineering communities, and are largely unavailable for critical scrutiny and rational adjudication. They not contribute to ethically effective or substantial solutions for engineers, and may even work against such contributions. In the next chapter I examine potential solutions to the tension introduced by paradigmatic background assumptions, and find them to be ethically ineffective and insubstantial solutions to tensions in engineering ethics.

Chapter 2 – Engineering History and Ethics

In the previous chapter I defined paradigmatic background assumptions, their role in developing causal schemes, and how they are deployed, defended, and revised. I identified six paradigmatic background assumptions forming the ideology an engineer will use in decision-making processes. Then, by using the idea of technological mediation, I argued that engineering is an inherently moral activity requiring critical analysis of decision-making processes and how these processes invite or inhibit ethically substantial and effective solutions to tensions created by paradigmatic background assumptions I identified. In this chapter I review the development of the profession of engineering and engineering education, including an analysis of the development and deployment of four tactics engineers have used to strengthen ethical decision-making processes in engineering. These four tactics include the use of codes of ethics by professional engineering societies to enhance the social legitimacy of engineers; the development of engineering ethics pedagogy, particularly from 1990 onward; the promotion of overly simplistic notions of objectivity to help guide engineering decision-making processes; and an emphasis infusing empirical success within engineering. I analyze these four tactics and determine that each approach is unable to address the critical tension created by the paradigmatic background assumptions I identified in the previous chapter. Ultimately a new tactic of addressing such tension is required, which I outline in the next chapter.

Engineering in the United States

In Europe prior to the end of the Renaissance period, to be an engineer was to be an *ingeniator*, a man who studied, designed, created, maintained and modified the *ingenium* ("ingenious devices") of missile-throwing and siege weapons increasingly used in warfare (Rae and Volti 24). It was not until the end of the Renaissance period that the term "engineering" began referring to an occupation with a specific set of skills and specialized areas of study. At this time engineering also began dividing into specific subject areas, beginning with the designation of *civil engineering* as a type of engineering with a set of skills distinct from engineering machines for warfare (Rae and Volti 2).

By the 19th century, the unique conditions of the U.S. colonialist expansion westward were reflected in the goals, methods and organization of engineering: the demands of the industrial revolution and new industrial corporations, the absorption of large numbers of immigrants, and the need to access recently acquired areas for natural resources (Rae and Volti 119). The capital demands of the second industrial revolution imposed a need for an unprecedented and massive infrastructure, eventually spanning North America, to produce and trade goods. It was during this time that the first priorities of engineering became apparent: "economical construction and low labor costs were paramount concerns; strength, durability, safety, and aesthetic appeal were of distinctly secondary importance" (Rae and Volti 129).

As was typical of applied sciences at the time, becoming an engineer required little formal education (Rae and Volti 120). Instead, apprentices or craftspeople utilized on-the-job training to acquire the necessary skills to become an engineer. The few men who were identified as engineers were highly sought after for the numerous infrastructure projects necessary to meet the demands of the second industrial revolution. In order to substitute many years of on-the-job training required for engineers at the time, formal education in engineering principles at institutions of higher education were created to allow individuals to learn the scientific knowledge necessary for engineering. By the end of the second industrial revolution in the late 19th century, engineering as practiced in Western countries included diverse fields of study, formal education, and a growing sense of professional duty separating engineering from other occupations.

Transitioning from an occupation to a profession requires an articulation of the amount and type of formal education required, but also an articulation of the principles describing how a profession is in the service of the public good. At the beginning of the 20th century engineers began characterizing engineering as an unselfish commitment to clients and society, not simply a means to another end (Rae and Volti 193). Just as doctors and lawyers enhance their professional legitimacy by committing to the positive service of society, engineers began considering service to the public as foundational to the practice of engineering (Rae and Volti 205). But unlike other professions at the time, engineering communities did not establish formal licensure requirements or governing boards dictating who was entitled or allowed to be called an engineer in their emerging profession. Today the professionalization of engineering remains as it was a century ago, and engineers continue to encompass a broad group of individuals who are trained formally or informally, licensed or unlicensed, engaged or not engaged with professional societies at their discretion.

By the early 20th century, a significant amount of post-secondary education was required before practitioners could consider themselves a professional engineer. An accreditation institution for engineering degree programs was created to evaluate and improve engineering curricula in higher education, in order to ensure that educational programs were meeting minimum requirements to produce competent, knowledgeable engineers. ABET, Inc., is responsible for the accreditation of engineering programs in the U.S., and, as of 2007, maintained accreditation of 1,798 programs at 368 institutions ("2007 Annual Report" 34). A portion of the criteria for accreditation requires students attain "an understanding of professional and ethical responsibility" as a part of a program outcome ("Criteria for Accrediting Engineering Programs" 2). A profession of engineers needs to demonstrate the ability to work toward the public good, and this requirement seems ostensibly provided to ensure a minimum level of ethical and professional responsibility toward the public. However, because no description is provided of what professional and ethical responsibility entails, specific criteria for evaluating the ability of a degree program to impart professional and ethical responsibility is unknown. Individual engineering programs are responsible for adequately demonstrating how a program establishes a student's competency in these areas.

Following the end of the Second World War, engineering has had to determine how to act responsibly and responsively toward broader social movements such as environmentalism, feminism, and the globalization of labor. These social movements are primarily translated into the pedagogy and practice of engineering by adapting existing engineering codes of ethics to include new standards for engineers to uphold and carry out. By including statements encouraging non-discrimination, concern for the environment, and responsiveness to the global contexts of engineering, professional engineering societies – who comprise part of the working body establishing the pedagogical standards of ABET accreditation – motivate engineering programs to respond to, and include broader, social movements as foundational to the practice of engineering. For example, the inclusion of statements that engineers ought to uphold public health and welfare in their work began to appear only in the 1930's, and statements about environmental stewardship began appearing (at the earliest) in the post-1960's wave of environmental consciousness. Statements in support of these newer ethical themes are now incorporated into nearly all iterations of engineering ethics pedagogy.

The highly public nature of engineering failures (or near failures) has also helped motivate engineering communities to be respond to social movements. Several failures are considered canonical case studies on the importance of engineering ethics in design and practice, and appear repeatedly in courses and academic papers on engineering ethics: the Bhopal, India chemical disaster in 1984; the Space Shuttle Challenger explosion in 1986; the Citicorp Center construction problem in 1978; and the Chernobyl nuclear reactor accident in 1986 (see Schinzinger and Martin, Humphreys). The public nature of these failures or near-failures continues to motivate engineers to analyze their role in ensuring the safety of manufactured products, machines, and other engineering projects.

There is a growing awareness by engineers that an emphasis on technical curricula is not sufficient to address problems introduced by the professionalization of engineering cultures, attempts toward inclusion of emerging social movements, and public engineering failures or near-failures. This is not to say that technical failures of machines or components of machines designed by engineers are not involved in the failures or near failures of engineering. I suggest, as others who study engineering ethics do, that complex social factors are increasingly identified as significant contributors to engineering failures or near-failures, whether these social factors are the products of individual engineers or an organizational hierarchy. Indeed, when analyzing case studies of failures or near-failures in engineering, the majority of engineering ethics attempts to identify social factors that informed the decisions that resulted in failures or near-failures.

In the next section, I present current tactics that are theorized to help contribute solutions to longstanding problems in engineering ethics. I analyze each tactic to examine if they are able to produce ethically substantial and effective solutions of the social tensions introduced by the paradigmatic background assumptions I identified. These four strategies include an examination of the code of ethics developed by professional engineering societies, pedagogical tactics of engineering ethics, attempts at a stronger objectivity, or an infusion of empiricism in engineering may help resolve ethical tensions in engineering ethics. Ultimately, I find these tactics unable to substantially and effectively resolve the longstanding tensions introduced by paradigmatic background assumptions that affect engineering decision-making processes.

Codes of Ethics

Professional engineering societies have created documents purporting to be a code of ethics to guide member engineers toward useful ideas that may help contribute toward ethically substantial and effective engineering decision-making. From the title

“Code of Ethics” one might expect these codes to be founded, as ethics is, in a particular ethical framework and conception of ethical theory. Without such an underlying framework or conception of ethics, any ethical code must rely on other motivations for enforcement, such as authoritarian control or pragmatic rule obedience. As I explain shortly, the lack of an ethical framework does not necessarily mean that codes are without ethical content, but it does (and will) prevent principled discussion of what rules ought to be included, emphasized, or prioritized within a code of ethics.

The preamble of the “AIChE Code of Ethics” is a representative example of the preambles of most codes of ethics promulgated by professional engineering societies:

> Members of the American Institute of Chemical Engineers shall uphold and advance the integrity, honor and dignity of the engineering profession by: being honest and impartial and serving with fidelity their employers, their clients, and the public; striving to increase the competence and prestige of the engineering profession; and using their knowledge and skill for the enhancement of human welfare. (“AICHE Code of Ethics”)

The codes following this preamble present the criteria chemical engineers should use to uphold and advance the integrity, honor and dignity of the profession of chemical engineering. To reiterate, the AIChE code is not atypical, and language in a “Code of Ethics” for major professional engineering organizations identify specific moral duties arising from a member's duty to the profession of engineering. The American Society of Civil Engineers (ASCE), recognized as the largest professional engineering society in the world with 140,000 members, states the fundamental principles of their code of ethics as:

> Engineers uphold and advance the integrity, honor and dignity of the engineering profession by:
> 1. using their knowledge and skill for the enhancement of human welfare and the environment;
> 2. being honest and impartial and serving with fidelity the public, their employers and clients;
> 3. striving to increase the competence and prestige of the engineering profession;
> 4. and supporting the professional and technical societies of their disciplines. (ASCE "Code of Ethics")

This first sentence is unambiguous in stating that all rules in the code following these fundamental canons clarify how an engineer can enact the fundamental principle to uphold and advance the engineering profession. It is important to note that no code states why its members should uphold and advance the engineering profession, although the preamble to the "Code of Ethics" used by the National Society of Professional Engineers (NSPE), despite using ambiguous language about the effects of engineering, may come close:

> Engineering is an important and learned profession. As members of this profession, engineers are expected to exhibit the highest standards of honesty and integrity. Engineering has a direct and vital impact on the quality of life for all people. Accordingly, the services provided by engineers require honesty, impartiality, fairness, and equity, and must be dedicated to the protection of the public health, safety, and welfare. Engineers must perform under a standard of professional behavior that requires adherence to the highest principles of ethical conduct. (NSPE "Code of Ethics")

By having a "direct and vital impact on the quality of life for all people," engineers have obligations to consider the lives of others, and particular virtues are included in this code of ethics to support this endeavor. However, how an engineer determines what "vital impact on the quality of life" he or she should strive to encourage in following this principle is not apparent using the preamble itself, nor additional sections of the code. Without a principled ethical framework to help guide an engineer, there may be multiple competing solutions to particular ethical problems, and adjudication between any two is impossible. The lack of an ethical framework demonstrates that the NSPE “Code of Ethics,” and codes of ethics in general, is unlinked to ethical theories at all. Instead, I argue that codes of ethics are a form of rule obedience, enacted and enforced by those who agree to participate in the organizations using them.

The lack of a carefully articulated ethical theory in engineering codes of ethics has several material and social consequences for engineering communities and engineers. Rae and Volti recognize the inability of codes of ethics in guiding the day-to-day practice of individual engineers, but maintain that codes of ethics ascribe a set of useful or positive duties to the profession of engineering (206). Ethics derives moral rules based on conceptions of right or wrong; rule obedience may appear to appeal to ethical principles, but tells us nothing of what ethical principles are deployed in their development. Such rules may advocate for particular virtues or a utilitarian focus on the greatest good for the greatest number, but without a derivation from ethical theories, the rules created are necessarily an arbitrary and external imposition. Particular rules may be developed and applied because an external source of control or authority imposes them (such as with systems of law), or because an individual assumes they are useful in attaining another good such as prestige, job security, prevention of imprisonment, etc., but rules qua rules are not developed and applied because they are worthy ends in and of themselves. Arbitrary rules have the effect of disallowing any principled discussion of what rule to choose over others. The capacity to create rules that are unjust, unfair, or immoral is present: Nazi Germany, the antebellum South, and Imperial Japan had many rules (legal and social) that we now understand as unjust, unfair and immoral because they were arbitrary and unprincipled. Rules without coherent ethical principles are obeyed simply because an external source of control compels us to obey them; they are not internalized or rooted in conceptions of good or bad like ethical theory.

Imagine an engineer, employed by a firm contracted to produce weapons for a government, finding he is unable to respond to or incorporate fundamental canons of engineering ethics – such as the duty to enhance human welfare and the environment – presented in a code of ethics because to do so would risk losing his job. Without strong statements of what the profession of engineering does to serve the public good or considers an ethical end to align it toward, engineers are unable to adjudicate between competing ethical claims.

Perhaps of more concern, codes of ethics in professional engineering organizations remove moral autonomy, defined here as the ability to act on ethical concerns using individual rationality and choice, by placing engineers under an externally imposed set of moral rules; even if moral rules are internalized they still act as limits to behavior as dictated by an outside entity (Lozano 248). While engineering codes of ethics may contain rules we think are important, positive, or good rules, by lacking coherent ethical principles rules are to be obeyed for the sake of the profession. Because of this, codes of ethics prescribe general ideals and behavior useful for the profession and any rule that supports the social legitimacy of the profession may be included. If a profession derives autonomy and legitimacy through social acceptance instead of moral principles, it must seek to please the society it serves, incorporating rules that might later be deemed unacceptably immoral.

One way to comprehend the lack of ethical theories in engineering codes of ethics is by understanding these codes as a pragmatic move granting engineers the freedom to use a flexible framework for ethical decision-making. There may be unique circumstances in engineering allowing such a pragmatic move. Taft Broome, noting the difference between science and engineering, states:

> What scientists admit as consistent enough results are those that are controllably predictive. What engineers admit as consistent enough results are those that can be used to obtain acceptable risks…. The point being made here is that neither universal acceptability of these risks, nor the acceptance of all affected rational persons is sought. (8)

Codes of ethics in engineering may help outline practical principles to delineate the acceptable bounds of risk in engineering decision-making. Shirley Fleischmann attributes three cultural conditions that required engineers to work toward practical instead of universal principles:

> (1) the move from principle-based to utilitarian criteria, (2) the decline of traditional principle-based instructions, (3) the complexity and rapidity of decision-making and the failure to integrate ethical reflection into it. (385)

The cultural shifts of the last century forced engineering communities, in deriving legitimacy from a commitment to the concerns of society, to incorporate new ideas and methods to reflect new social realities. This is reflected in updated codes of ethics and professional standards. However, it should be noted that statements obligating engineers to consider public health and welfare, environmentalism, and global contexts of engineering begin to appear only *after* each corresponding social movement entered an initial period of popularity with the public at large.

I argue that engineering codes of ethics are rules designed to legitimate the social standing and power of engineers and engineering communities without using any coherent ethical principles. By creating a system of moral rules in the absence of any ethical system, codes of ethics are enforced through rule obedience: engineers use these rules because their status as a professional depends on it. Particular rules in a code of ethics may be regarded as agreeable, moral, or good to society at large, but they do not explain why they are regarded as such, merely that they appease enough of those in power to grant legitimacy – with all the attendant benefits. If a professional engineering organization discovered that it would be beneficial for the profession to make a statement excluding certain groups from being engineers, nothing in any code would prevent this from occurring, provided the statement of exclusion upholds and advances the profession of engineering and does not substantially conflict with another rule - which may be amended, altered or dropped if so desired. Because engineering codes of ethics lack coherent ethical principles and rely on self-interest alone, these codes qua codes are unable to offer opportunities for effective or substantial analysis or resolution to the tensions created by paradigmatic background assumptions in engineering ethical decision-making processes.

Teaching Ethics

In this section, I analyze two common pedagogical strategies deployed and developed in teaching engineering ethics. Developed in response to evolving ABET criteria requiring an integrated knowledge of professionalism and ethics from engineering students, these pedagogical tactics include the presentation of stand-alone undergraduate courses in engineering ethics and the integration of case-studies in engineering coursework. Combined, these strategies on engineering ethics are designed to create a foundation for ethical decision-making processes that engineers should use throughout their careers. Therefore these two strategies may be examined together for how they do or do not address the persistent tensions in engineering ethical decision-making processes introduced by paradigmatic background assumptions. Ultimately I find that these strategies use an ethical framework informed by the same paradigmatic background assumptions creating persistent tensions, and are unable to effectively or substantially analyze or resolve tensions introduced in engineering ethical decision-making processes by paradigmatic background assumptions.

Although there is some debate about specific pedagogical goals of engineering ethics education, Michael Davis notes that there is broad agreement among U.S. engineering ethics educators to provide undergraduate students with a curricula that leads to an “a) increased ethical sensitivity; b) increased knowledge of relevant standards of conduct; c) improved ethical judgment; and d) improved ethical will-power (that is, a greater ability to act ethically when one wants to)” (qtd. in Heckert 304). I refer to these four goals as the primary components of the pedagogical goals of engineering ethics curricula; that is, these goals generally prescribe what engineering ethics is supposed to teach about moral reasoning among undergraduate engineering students. Regional, philosophical or discipline-specific differences in a program may complement or enhance the four goals outlined above, and thus the moral pedagogy used in specific engineering programs may include other criteria. Nevertheless, from a survey of pedagogical literature on engineering ethics, the four goals listed above appear in all engineering ethics curricula, and thus comprise minimum pedagogical goals for engineering ethics in engineering programs.

Case studies are used to illustrate moral principles, dilemmas, and possible resolutions among both stand-alone engineering ethics courses and integrated curricula, and are the primary strategy used to explicitly teach engineering ethics (Heckert 306). Several introductory texts on engineering ethics (see Schinzinger and Martin, Humphreys) use fictional or historical case studies that require ethical decision-making processes for resolution. In examining moral psychology and moral pedagogy, Chuck Huff and William Frey state that case studies engage the goals of moral pedagogy by

- Motivating students to learn the basic concepts so they can talk about an interesting case
- Putting students in roles where they are likely to experience different moral intuitions as they take different positions in a case
- Putting lessons in narrative form so that they can be remembered more easily
- Providing specific instances that can be used as metaphors or analogies for new instances
- Providing practice in safe-but-realistic simulations for ethical problem solving
- Providing a venue for students to hear the moral intuitions of others, intuitions that can come from several perspectives
- Providing an opportunity to build moral consensus and moral community both by coming to agreement and by agreeing to disagree about realistic moral problems in the field (Huff and Frey 398-399)

The primary difficulty of case studies is that they serve as an abstraction of a single event (fictional or historical), and focus on the actions (or potential actions) of an individual engineer (Bucciarelli 141). Case studies also typically admit that there could be, or were, several possible or acceptable resolutions to particular engineering ethical dilemmas. Even where case studies refer to social context of engineering, impetus for problem resolution is individual, even if the individual is asked to provide a problem resolution at a level of an organization they would not, in the day-to-day, be able to change – i.e. “Should organization X have done Y?”

Many case studies also represent one particular type of engineering ethical decision-making as the paragon (or perhaps worst-case) scenario of an engineering ethical dilemma: the process by which an engineer considers “whistle-blowing” an organization for their action or inaction (Swierstra and Jelsma 311). The insistence that an engineer ought to consider ethical actions as an individual effort stands in tension with the idea that engineers are members of large organizations whose members may have competing interests, ideas, values, processes, leadership styles, and identities. This tension has been widely reported on, but lacks a critical analysis of potential resolutions (Schinzinger and Martin 1-37, Bucciarelli, Broome 4, Rae and Volti 137-147). These potential or perceived solutions may even be in conflict with each other, as seen in paragon examples of whistle-blowing requiring an engineer to face a dilemma between maintaining a sense of fidelity toward a client or employer with potential public harm. Tsjalling Swierstra and Jaap Jelsma identify four criteria for an individual to be considered responsible for an action:

1. Rationality: To consider an actor responsible, he or she should be imputable [...] being in possession of one's rational capability at the moment one performed the imputed action. […]
2. Causality: The actor should … have performed the action [or inaction when he or she should have] for which he or she is considered responsible. […]
3. Freedom: The actor should have acted on his or her own free will … he or she should not have been under external pressure or hindered by circumstances outside his or her control. […]
4. Knowledge of consequences: The actor can be held responsible for the consequences of his or her actions only if these were or could have been foreseen. […] (312-313)

Whistle-blowing meets these criteria, and analysis of case-studies involving whistle-blowing attempts to address the considerable lack of freedom an engineer will face in decision-making from management, corporations, clients, and others (Swierstra and Jelsma 313). But as Swierstra and Jelsma conclude, few criteria besides the first of these will apply to the day-to-day activities of an engineer (Swierstra and Jelsma 314). Using incomplete or inappropriate notions of moral responsibility for the actions of engineers, engineering communities will be unable to substantially or effectively resolve the day-to-day tensions within engineering ethics created by paradigmatic background assumptions, regardless of how case studies portray how decision-making processes should be. This is not to say that engineers are unethical or will forever be unable to resolve this tension, but rather that the pedagogical tactics of engineering ethics, as the three other methods I have identified in this chapter, do not allow critical analysis of, or substantial and effective resolution toward, the tension introduced by paradigmatic background assumptions.

Using case studies in engineering pedagogy does not, and cannot, resolve the tensions in engineering introduced by paradigmatic background assumptions. By being unable to critically analyze paradigmatic background assumptions, the use of case studies encourages engineers to remain uninformed of the effects of paradigmatic background assumptions on decision-making processes.

A More Objective Engineering

As I argued in Chapter 1, paradigmatic background assumptions operate with several features that contribute to their tacit, uncritical acceptance. But suppose an engineer realizes that paradigmatic background assumptions are not necessarily supported by evidence alone, and then claims that an infusion of objectivity in engineering decision-making will remove less well-supported paradigmatic background assumptions. If he or she is able to determine what assumptions *are* supported by more objective standards, or is able to modify assumptions to conform to more objective standards, he or she may be allowed to integrate them into engineering ethical decision-making processes.

In her paper “Dilemmas of Objectivity,” feminist philosopher of science Marianne Janack clarifies “objectivity” conceptually, demonstrating how simplistic notions of objectivity are coherently insufficient, and will introduce significant tension if used without careful analysis. Janack outlines problems that programs calling for greater objectivity will encounter, demonstrating that the term “objectivity” encompasses a range of definitions that simplistic notions objectivity cannot capture, and ultimately fail to account for competing forms of objectivity. Her purpose is to clarify the concept of objectivity in order to strengthen feminist engagement with, and claims about, the particular forms of objectivity deployed and defended in science. As a practice of applied science, engineering exhibits similarities with scientific practice that allow Janack's conclusions to be imported into engineering, which I explore shortly.

Janack begins her paper by providing several examples where the use of a form of objectivity is contradictory or in tension with other common notions of objectivity. Commonly, objectivity is considered to be concerned with “truth,” or at least an appeal toward “...the world as it is independently of our desires about how we want it to be”

(Janack 267). But a failure of objectivity is not always considered an epistemic failure; failures of objectivity may also involve (1) a failure to recognize *evidence* that is true or an accurate reflection of “the way things are,” or (2) a *claim* that fails to correspond to “the way things are” (Janack 268). Both faulty reasoning *and* falsehood comprise two types of failures of objectivity.

But, Janack adds, even conceiving failures of objectivity as relying *only* a product of faulty reasoning or falsehood does not include certain examples considered failures of objectivity. A person may have access to “all the facts,” and not be subject to a falsehood, but still fail to be “objective” in a colloquial, tacitly assumed sense. Moral failures, or a failure to be fair to the evidence, can also be considered a failure of objectivity. Even if one ends up at a seemingly objective result, the process of *how* one arrives at that conclusion is also important (Janack 270). Consider the following joke from Plato and a Platypus Walk Into a Bar:

> A judge calls the opposing lawyers into his chambers, and says, “The reason we're here is that both of you have given me a bribe.” Both lawyers squirm in their seats. “You, Alan, have given me $15,000. Phil, you gave me $10,000.”
>
> The judge hands Alan a check for $5,000 and says, “Now you're even, and I'm going to decide this case solely on its merits.”
> (Cathcart and Klein 168)

While it appears that the judge is objective to both lawyers by equalizing each of their bribes, one would still question the objectivity of a judge who takes bribes in the first place. The point Janack and the joke wish to make is that the only conception of objectivity shared by individuals is that objectivity is promoted as a sort of ideal, yet without criteria as to what counts as objectivity or what counts as a failure of objectivity (271).

Janack's analysis of objectivity as a diverse, cobbled-together concept undercuts feminist analysis of objectivity as a false dichotomy, masculine bias, or mischaracterization of science (271). By not acknowledging the different, sometimes contradictory concepts of objectivity, feminist engagement with objectivity is appropriately open to a variety of criticism (Janack 272).

Janack divides the remainder of her paper into three sections: first she describes the interaction of feminism with questions of objectivity; then by describing the myriad ways objectivity is actually used in discourse; and finally by showing the ways feminism can engage with objectivity and respond to criticisms about feminist objectivity. In what follows, I summarize each section of her paper and argue that a general call for greater objectivity in engineering will be unable to produce substantial or effective resolutions to the tensions created by paradigmatic background assumptions in engineering ethics I identified previously.

Feminist engagement with objectivity eventually must respond to the paradox of bias: how can anyone say that some biases (sexism, racism, etc.) are inappropriate to introduce in scientific practice, but other biases (feminism, critical race theory, etc.) may be okay to introduce (Janack 272)? Some feminist thought has responded to the paradox of bias that the problem with objectivity is not that biases themselves are bad, but that the idea of “perspectival aperspectivalism,” or “the view of some people in particular” has been too often falsely passed off as objective (Janack 273). In compiling a list of different uses of the word “objectivity,” Janack shifts the concept of objectivity to an appropriately named “plural objectivities.” The list of “objectivities” Janack gathers from literature include:

1. Value neutrality;
2. Lack of bias, bias that includes:
    a) Personal attachment;
    b) Political aims;
    c) Ideological commitments;
    d) Preferences;
    e) Desires;
    f) Interests;
    g) Emotion.
3. Scientific method;
4. Rationality;
5. An attitude of 'psychological distance';
6. 'World-directedness';
7. Impersonality;
8. Impartiality;
9. Having to do with facts;
10. Having to do with things as they are in themselves; as universality;
11. Disinterestedness;
12. Commensurability;
13. Intersubjective agreement. (275)

These conceptions of objectivity cover a variety of moral virtues, epistemic goods, legal and political goods, psychological attitudes, and ontological commitments. Using the phrase "perspectival aperspectiveness" to describe objectivity covers up the variety of competing ideas conceptually contained within, and allows philosophers to maintain the hope of discovering a unifying or supreme value that may provide a common ground for a term as unstable as "objectivity" (Janack 276). This led to a variety of "successor virtues" that placed epistemic responsibility, reflexivity, dialectical responsiveness, democratic openness, thinking from the margins, intersubjective agreement, or trustworthiness as the primary site of objectivity (Janack 276). All the attempts at defining a successor virtue for objectivity are, according to Janack, attempts to refashion "objectivity" as a unified concept, despite its amorphous nature (276).

Janack believes there are problems with attempts to reclaim "objectivity," but she does not think the work of reclamation is entirely unimportant. Without the work of analyzing faults in objectivity and providing new conceptions open to critique and further analysis, it may never have become apparent that objectivity is as conceptually fractured as it is (Janack 277). However, treating the reclamation as an end in itself covers up messy boundaries of objectivity, and closes up avenues of inquiry where the operation of different standards and applications of objectivity could be made salient (Janack 277).

Engineers are, by trade and education, not seekers of objectivity or impartiality. As I identified in the previous chapter, engineers are implicitly and explicitly taught to materialize morality using ideas and concepts of applied science. Achieving objectivity or impartiality is not compatible with an engineering that alters the perceptions and potential actions of individuals, although engineering may occasionally achieve specific forms of objectivity. Furthermore, most of Janack's "objectivities" stand in stark contradiction to the goals of engineering, even if engineers may wish otherwise. On this ground, promoting a "greater objectivity" is ineffective for producing substantial or effective resolutions of the tension arising from the paradigmatic background assumptions I identified in the prior chapter. In the next section, I analyze the idea that an infusion of empiricism in engineering is able to ameliorate tensions in engineering ethics, and argue that as with "objectivity," engineering may not be so compatible with empiricism.

Empiricism and Engineering

Philosopher of science Miriam Solomon states that we have greater agreement about the criteria for what scientific success is not than we have for what it is (15). She examines where different concepts agree, in order to determine if there can be a more complete idea of scientific success teased from the overlap.

Solomon's analysis of scientific success focuses on the various notions of empirical success. It should be noted that because of the disunity of scientific practice, Solomon does not wish to create a definition of empirical success, as she believes that any attempt to define empirical success will be over-generalized and inapplicable except in specific circumstances. Instead she describes the variety of features encompassing empirical success in order to demonstrate that empirical success is a family of related successes that lack any unifying conceptual scheme except that they are contingent on a "real world" external to inquirers (27, 31).

The types of empirical success that Solomon catalogues demonstrates that empirical success is contingent on situation, historical period, available data, models, theories, people, and fields (28). The type of empirical success used in one setting may not work in others; for instance, the explanatory power of sea-floor spreading relied on no experimental or technological success, and very little predictive success due to the geological timeframes presupposed by their theory (Solomon 23). Other empirical successes relying on experimental success – such as the production and testing of insulin - may not yield explanatory success, or at least may not initially yield explanatory success, yet both examples above are considered to be empirical successes.

Solomon argues that we cannot rely entirely on any well-known paradigm to help define empirical success: different situations may hold empirical success to be more or less contingent on predictive accuracy, explanatory power, technological success, or manipulative success (27). She concludes that a more useful understanding of empirical success requires analyzing examples of empirical success instead of general definitions.

As I stated earlier during the analysis of Janack's notion of objectivities, engineering communities are not primarily concerned with producing unbiased or impartial accounts of the world. Rather, engineering communities use concepts of applied science to materialize morality during problem-solving in the world. Engineering may contain significant overlap with the information contained in scientific communities, but does not follow the empirical processes Solomon identified. Engineering therefore is merely “unsurprising applications of noncontroversial theories” (Solomon 30). Using noncontroversial theories implies that engineering communities do not (and cannot) exhibit the robustness or significance that is expected of empirical successes. Thus knowledge generated in engineering communities is not expected[1] to conform to empirical success, although on occasion it may. This is not to say that engineering is devoid of empirical content, but that engineering does not have the ability to produce the empirical success possible in scientific communities. An analysis of engineering communities will provide useful knowledge to sociologists, philosophers of science and technology, and other related fields, but the practice of engineering does not overlap with the empirical success Solomon describes above.

[1] Empirical success in engineering practice is often a result of error or serendipity more than any specific program of study. For example, see the accidental discovery of lithium-7 as a fuel for thermonuclear devices during the Castle Bravo test by the U.S. government - which also ended in radiological disaster.

Attempts to infuse empiricism among engineering communities will not shift engineering away from materializing morality for others, nor should we attempt to promote such a fundamental shift in engineering. Rather, calls for an infusion of empiricism into engineering will have the affect of masking the paradigmatic background assumptions that affect engineering ethical decision-making from inquiry and resolution. Any attempt to infuse empiricism into engineering as a method to resolve persistent and intransigent tensions created by paradigmatic background assumptions will not produce ethically substantial and effective resolutions.

The four methods used to address the persistent tensions in engineering ethical decision-making I analyzed in this chapter – the use of codes of ethics, pedagogical strategies in engineering ethics, attempts at greater objectivity, and calls for infusing empiricism in engineering – will not help engineers produce ethically substantial or effective decision-making processes. Nor will these tactics allow for the development of a framework for understanding, analyzing, and resolving tensions in engineering decision-making processes introduced by paradigmatic background assumptions. What is needed is a new approach toward understanding the role of paradigmatic background assumptions in engineering decision-making processes, including methods for an analysis and resolution of the ethical tension they can and do introduce. Using the work of Helen Longino's naturalized epistemology and philosophy of science I begin outlining such a method in the next chapter. The framework understanding of paradigmatic background assumptions introduced by her method will provide the necessary space to discuss, revise, reject and embrace particular paradigmatic background assumptions in engineering decision-making processes, allowing for coherent decisions that are ethically substantial and effective.

Chapter 3 – Naturalized Empiricism and Philosophy of Science

Engineering is an inherently moral activity mediating between individuals and the world, solving material problems by inviting or inhibiting particular perceptions and actions. As such, engineers need coherent problem-solving methods that are ethically substantial and effective, and lead to solutions without introducing additional ethical tension. As I identified in chapter 1, there are a collection of paradigmatic background assumptions operating in engineering cultures influencing problem identification, analysis, and resolution. These background assumptions operate as normative guides for engineering problem-solving and, whether learned explicitly or tacitly, often mask their own influence and are not available for critical analysis or adjudication among competing background assumptions. I argued that these paradigmatic background assumptions do not help produce ethically substantial or effective problem resolutions. The four approaches I identified in the previous chapter – the use of codes of ethics, pedagogical strategies in engineering ethics, or calls for greater objectivity or empiricism in engineering – produce similarly limited results.

In this chapter I identify locations where Longino's development of a naturalized empiricism and philosophy of science is compatible with engineering cultures, in order to understand how her analysis may impact or mitigate the tensions introduced by paradigmatic background assumptions. Recall the paradigmatic background assumptions at issue:

1. Engineering is a morally positive. At the very least, it is morally neutral.
2. Engineering is empirically adequate, or heavily empirically based.
3. The profession of engineering, and products of engineering, is accessible to all individuals regardless of social, cultural and personal characteristics.

4. Engineering is a practice of solving material problems within the context of corporate cultures.
5. Engineering as practiced in the "Western" or "first-world" is the model for engineering elsewhere or everywhere.
6. Technology and the products of engineering are the principle way to improve the human condition.

It is important to restate that the scope of this thesis will leave as unresolved the substantiation or rejection of these assumptions, beyond noting that these assumptions operate as an ideology that misrepresents or distorts the real world to greater or lesser extents. What I *am* going to do, however, is describe Longino's framework understanding of how paradigmatic background assumptions operate within science in order to demonstrate a method for the discussion, analysis, rejection or uptake of paradigmatic background assumptions in engineering.

Naturalized Empiricism

Longino develops an account of naturalized epistemology and philosophy of science in order to create an account that is both normative and descriptive toward knowledge generation in scientific communities. Naturalized epistemology provides a historically sensitive account of how so-called "good" science has operated, and a normative philosophy of science describes features of science that should be requisite for the successful production of knowledge (Potter 97). Much of Longino's work rests on a socialized account of knowledge generation; that is, the idea that producing objective scientific knowledge is a collective social endeavor dependent on complex practices within communities of scientists (69). In the next section I describe how Longino arrives at her normative and descriptive account of knowledge generation, beginning with her criteria for evidential reasoning and empiricism in science. As an applied science, engineering exhibits similarly complex social action, and much of her account will be useful to reframe ethical decision-making processes in engineering. However, rather than attempt to recast in engineering terms the entirety of Longino's naturalized epistemology, I articulate ways Longino's account shares similar social features in engineering decision-making processes. I conclude that her naturalized epistemology and normative theory of scientific knowledge is methodologically valuable in addressing the persistent tension introduced by the background assumptions within engineering, particularly those affecting engineering decision-making processes listed at the beginning of the previous chapter. I conclude that her account provides an empirically adequate normative understanding of engineering ethical decision-making that may be able to resolve tensions engineers encounter while mediating the world and solving material problems, which I identify afterward.

In the preface to Science as Social Knowledge, Longino states that her book “provides an account of scientific inquiry within which to make sense of scientific debates that have social and normative dimensions” (ix). She does so in order to provide an account of the relation of social values to scientific inquiry, a subject she finds often overlooked by traditional philosophers of science (ix).

Longino identifies two types of values, *constitutive* and *contextual*, that serve as arbiters in disputes between competing theories. Constitutive values bound acceptable scientific practice and include goods like truth, accuracy, simplicity, predictability, and breadth (Potter 99, Longino 4). Contextual values are the social, political, cultural, and psychological values brought to bear by individuals and groups within science when deciding what *ought* to be in the world.[2] Here we see that Longino's distinctions of values may be imported, without heavy modification, into engineering practice, with constitutive and contextual values respectively corresponding to the primacy given to math and science in engineering practice, and the social influences that affect the practice of engineering.

Longino's use of values in science immediately raises two problems: 1) how do or how should scientific theories shape moral and social values, and 2) how do or how should moral and social values shape science? Casting the first question as a consequence of the second, Longino states that these two questions are really about integrity and autonomy within science, that are in turn about a much larger and deeper question of how evidence is connected to the reasoning process at all. Thus in order to arrive at a philosophical analysis of values within scientific reasoning Longino begins with a philosophical analysis of evidential reasoning and its role in scientific practice (3-4). We expect engineering to conform, at least in instances where empirical justification of particular actions is provided, to forms of reasoning similar to what Longino identifies in scientific practice.

Reasoning, Longino postulates, involves a determination of the "logical relations that exist among sets of propositions," and does not come about exclusively from common notions of "linguistic calculations" connecting propositions to each other (38). Instead, reasoning involves an ability to determine the consistency,

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[2] I reiterate my insistence that for the purposes of this thesis, distinctions between facts and values are a strictly social creation and not of epistemological significance. While I will continue to use Longino's distinction of constitutive and contextual values when explaining her analysis, when applied to the context of engineering I will collapse her distinction, instead using the phrase paradigmatic background assumption. I do so in order to produce a more fruitful account of how background assumptions operate among engineering communities, as we will see shortly.

inconsistency, contradiction, implication, inclusion in a class structure, and causal relations of propositions, among a vast array of possible relationships to be examined in any reasoning process (Longino 38-39). Longino is not trying to undermine our faith in reasoning; rather, she wishes to demonstrate that there are many stages of reasoning undertaken to connect a particular object, event or state of affairs to a particular hypothesis, model or theory (40-41, Potter 117).

Longino contrasts her analysis of evidence as inference of theory with two major philosophical schools of thought in science – logical positivists and holists – and how they reconcile evidence as inference of theory. For logical positivists what counts as evidence "...is determined by the form of hypothesis sentences and evidence sentences... [therefore] inference to a hypothesis is not mediated by possibly value-laden assumptions" (Longino 48). The primary problem of this method, though, is that very few sentences express relations between evidence and hypothesis appropriately or straightforwardly (Longino 49). Furthermore, any attempt by logical positivists to demonstrate evidence in favor of a particular theory will also rely on background assumptions that link evidential relations of a theory to other hypotheses within a theory. Thus a circular arrangement is created among evidence, hypothesis and theory that will require background assumptions to enter the evidential reasoning process as necessary elements for connecting particular hypotheses of a theory to each other (Longino 49-50).

Holists in contrast insist that "elements of a theory, including its supporting data, can only be understood in the context of the whole," thus allowing for background assumptions to provide for the incommensurability of a particular theory

(Longino 27-28). Researchers in different scientific programs may quite literally be unable to “see” what other researchers, working in incompatible research programs, are seeing. It may be possible to reconcile incommensurable theories by understanding that terminology and phenomenology will be different among individuals belonging to different, incompatible research programs (Longino 53). The problem with traditional holism lies in the unstable meaning of terms used to connect evidence to hypothesis, in addition to the idea that competing theories can be both mutually incommensurable and mutually inconsistent with each other, that is, competing theories may not be judged using the same standards but may also preclude the use of a competing theory. For example, heliostatic cosmology would interpret the steady alternation of day and night as example of a spinning Earth, while geostatic cosmology would interpret the same observation as evidence that the sun moves about a stationary Earth. The alternation of night and day supports both theories, but each theory is incommensurate with the other and uses a fundamentally inconsistent set of assumptions (Longino 45). Thus the relationship between evidence and the theory it supports will become an unbreakable link, yet may stand in tension with other competing theories. This seriously undermines the usefulness of <u>any</u> evidence in supporting one theory over another, and it may not be possible to reconcile any incommensurate and inconsistent theories with each other unless additional criteria are defined (Longino 57).

The conclusion Longino reaches, as I briefly mentioned in the first chapter, is that theory is always underdetermined by the evidence given in support of it, and thus a particular scientist (or scientific community) must rely on criteria other than evidential reasoning to adjudicate between two competing yet equally supported theories (41). By describing the underdetermination of theory by evidence, Longino wishes to reframe questions about how much or what type of evidence count toward a theory, toward a focus on how to account for background assumptions bridging the logical gap from data to evidence for a particular hypothesis, model or theory (Longino 60).

On the use of evidential reasoning with engineering, we need not spend much time demonstrating that engineering, as a practice of applying scientific knowledge to solving material problems in the real world, faces similar problems of underdetermination during problem identification, analysis, and resolutions. Given the possible resolutions to a particular material problem, attempting to justify decisions on empirical sufficiency alone will always be mediated or constrained by paradigmatic background assumptions. Paradigmatic background assumptions narrow down potentially infinite lists of material problems to be addressed by identifying problems with more valuable solutions, creating a logical gap in how problems are identified, by whom and for whom. An engineer, operating with the assumption that technology is the principle way to improve human welfare, will view a lack of clean water in non-Western countries as a technical (as opposed to social) problem. He or she will use an evidential reasoning process actively linking Western standards of water quality and access to improving water quality and access in these areas. He or she may devalue or undervalue the effects of social systems, e.g. as above, an engineer may not seek as much, or any, information on how social systems contributed to a lack of access to clean water, or how water use may be significantly different in another part of the world, and instead seek technical details related to clean water access. Put another way, the ideology of an engineer, informed by a set of paradigmatic background assumptions, will circumscribe the range of material problems in need of engineering solutions.

Underdetermination in science or engineering faces an inductive dilemma: if background beliefs mediate between evidence and hypothesis, and both evidence and hypothesis rely on other background assumptions, are there are any standards of objectivity (or objectivities, to use Janack's term) that could be used without resorting to pernicious circular reasoning that casts objectivity in scientific practice as similarly unfounded as, say, mysticism or pseudoscience? To put it another way, will the use of background beliefs that are themselves contingent on other background beliefs lead us to an infinite regression that proves untenable and logically unsound? Under a positivist approach it may seem that theories are "turtles all the way down,"[3] and to a holist it might seem that describing theories in this way ignores how social location – i.e. the experience-based viewpoints of the world – shape and define how particular inquirers view evidence.

Longino largely sidesteps this dilemma and declares that objectivity (singular) within scientific communities is secured by the "social character of inquiry" among those communities (62). Contrasting the objectivity of scientific practice with the objectivity of individual scientific practitioners, she argues that standard accounts of science conflate the two and result in individualized accounts of knowledge generation, and it is more appropriate, historically and philosophically, to understand objectivity as the product of particular processes of scientific practice existing

3 Referring to an apocryphal story about the world being held up by a tortoise, which is held up by another tortoise, *ad infinitum.*

independent of individual practitioners (66-67). Scientific knowledge, therefore, is the product of social inquiry between practitioners, not the aggregate result of scientists working individually:

> ...scientific knowledge is, after all, the product of many individuals working in (acknowledged or unacknowledged) concert. As noted earlier, scientific inquiry is complex in that it … consists not just in producing theories but also in (producing) concrete interactions with, as well as models... of, natural processes. These activities are carried out by different individuals... [and] a single complex experiment may be broken into parts.... The integration and transformation of these activities into a coherent understanding of a given phenomenon are a matter of social negotiations. (Longino 67)

Longino states that while peer review is one such place for the social processes of scientific practice to play out, it is not the only place, as "...what will become scientific knowledge is produced collectively through the clashing and meshing of a variety of points of view" (69). What happens *after* peer review may be more important, as other practitioners cite, modify, argue and criticize published work (Longino 69).

Longino spends a great deal of time explaining the social nature of scientific communities and scientific knowledge in order to claim that scientific knowledge is a social product, but no such step is necessary to create a socialized understanding of engineering. As I described in the second chapter, engineering is an endeavor of large, complex communities working in collaboration to solve material problems, often in corporate or governmental settings. The process of solving material problems will involve communities of individuals working together to identify, analyze, and determine solutions for larger group problems. While engineering may not share all the specific or particular features of an empirically-based program such as science, the shared social nature of problem solving will allow Longino's analysis of knowledge generation to have similar consequences in engineering, as I demonstrate shortly.

The social nature of knowledge generation demonstrates the public nature of scientific practice (which Longino terms “publicity”), as science is both a public resource in the funding and education of scientists, as well as being amenable to public criticism and intersubjectivity (70). The public nature of science and the reflexive action of scientists in revising or dismissing theories in light of new evidence or new relations between evidence explains why science is still considered objective in the face of evidential relationships mediated by background assumptions (Longino 70-71). Longino explains further:

> As long as background beliefs can be articulated and subjected to criticism from the scientific community, they can be defended, modified, or abandoned in response to such criticism. As long as this kind of response is possible, the incorporation of hypotheses into the canon of scientific knowledge can be independent of any individual's subjective preferences. (73-74)

It should be noted that the public, intersubjective nature of science does not *guarantee* objectivity, but is a requirement for any type of objectivity to exist at all. A group of scientific practitioners may exhibit a great deal of intersubjectivity, but still be unable to produce objective scientific knowledge of the kind Longino describes. Longino later identifies several conditions where intersubjective agreement has failed or could fail to produce objective accounts, but for now I acknowledge that intersubjective agreement is a prerequisite to, but not the sole determinant of, objectivity in science.

Before proceeding, it will be useful to take a moment to examine Longino's use of objectivity in light of Janack's analysis of objectivities. As mentioned in the previous chapter, Janack recasts “objectivity” as “objectivities,” articulating a conceptually coherent understanding of how objectivity is deployed and defended in scientific practice. Her conclusion is that a universal form of objectivity is largely an epistemological distraction, and is not useful when individuals discuss different and competing forms of objectivity. A more nuanced understanding of objectivities allows individuals and communities to create a space for adjudication of the many competing forms of objectivity.

Longino, however, clearly defines "objectivity" as intersubjective agreement. Is her use of the term "objectivity" misleading or inappropriate, given Janack's placement of intersubjective agreement as one of many forms objectivity may take? I argue that Longino's use of intersubjective agreement is misleading but not inappropriate, insofar as intersubjective agreement is *part of the process* of her naturalized epistemology, but not a successor or unifying term for objectivity. If scientific knowledge is the product of public, social processes, then for individuals to come to agreement about interpretations of *any* data will require deliberation and agreement on terms and background assumptions affecting interpretation. Depending on how prior experience articulates a particular understanding of regular features in the world between individuals, this process may be explicit or non-explicit. I depart from Janack by joining with Longino and classifying intersubjective agreement as the method of securing objectivities among individuals and communities, a requirement for the production of objective scientific knowledge but not a form of objectivity itself.

Longino states that while "the relation between hypotheses and evidence is mediated by background assumptions that themselves may not be subject to empirical confirmation or disconfirmation," inquirers should not rely on empiricism alone to produce objectivity (75). Background assumptions may be a product of metaphysical or normative considerations, but the shared social setting of inquiry determines the usefulness of particular background assumptions in assessing the role of evidence to theory (Longino 75). I find this to be an unnecessary step. Fact/value holists, as I discussed in my first chapter, say that background assumptions are not devoid of cognitive content or without the ability to be refined or critiqued: the body of evidence needed to revise a background assumption may be large but is not closed off from critical scrutiny entirely, our wishes to the contrary notwithstanding.

Evidential reasoning suffers similar constraints as Longino identified when engineers move from problem identification toward identification of potential solutions. Due to the complexity of particular material problems and the social forces involved with most engineering projects, pressures to conform to prior solutions identified by others – even those resulting in less ethically substantial or effective solutions – may be given preference over other potential solutions. This persistent feature of engineering has variously been called "technological lock-in" or "technological momentum" (Pool 161, David, Arthur). Technological lock-in is responsible for the adoption of several technologies – and therefore many derivative technologies – that gained dominance not because of technical superiority or elegance when compared to similar technologies, but due to the influence of political or social factors considered "outside" the scope of engineering. VHS videocassettes, QWERTY keyboards and gasoline-powered automobiles are examples of technologies that are theorized by some to have been technically matched by the alternatives available in their early development. The alternative technologies lost because dominant technologies had *slight* technical or market advantages at a particular point in time and gained nearly inescapable momentum toward dominance that alternative technologies could not compete against, even if they may have been technically superior or more appropriate if given the same energy and resources (Pool, David, Arthur).

Thus problem identification and potential solutions have been, and will be, defined within particular technological regimes that are locked-in or are difficult to change. These regimes may be so entrenched, i.e. that they define problems *and* potential solutions internally, that it may become exceedingly difficult for technically superior or more appropriate technology to gain ground. The specific action of technological lock-in is largely outside the scope of this thesis, but helps demonstrate how evidential reasoning processes within technological regimes will not sufficiently enable substantial or effective problem resolution of the intransigent features of engineering described in prior chapters.

In her analysis of reasoning and evidential relationships, Longino concludes that both constitutive and contextual values in scientific reasoning are social, insofar as they are the products of the discursive interactions of individuals and communities (Potter 114). This deliberative and reflective reasoning is what produces objective scientific knowledge, although it is not inherently a guarantee of objectivity. In order to identify normative reflexive processes that help the discursive interactions of scientific communities, Longino identifies and develops four practices which I explore in the next section.

Toward a Normative Theory of Science

Up to this point the goal of Longino's analysis has been to demonstrate that scientific reasoning and scientific practice are highly complex social processes. In order to satisfy the requirements of transformative critical discourse, she identifies four practices that scientific communities must provide: 1) recognized avenues for the criticism of evidence, methods, assumptions and reasoning; 2) shared public standards; 3) shared community response, and; 4) an equality of intellectual authority. These criteria also require the use of valid reasoning and appeals to empirical evidence in order for evidential reasoning to take place, as detailed above. Additionally, she identifies three conditions where scientific communities will *still* fail to produce objective accounts, even if they follow the four practices she identifies. What follows is an exploration of the four practices and three conditions she outlines. Afterward, I analyze how these four practices are able to be imported into engineering decision-making processes, and then use this method to analyze the background assumptions I listed at the beginning of this chapter.

Recognized Avenues for Criticism. Longino states that there must be "publicly recognized forums for the criticism of evidence, methods, and of assumptions and reasoning" (qtd in Potter 119). Publicly recognized forums must be able to critique all aspects of reasoning and evidential processes, including the background assumptions operating in those processes, provided such criticism advances understanding. Longino states that this also requires that "critical activities should receive equal or nearly equal weight to 'original research' in career advancement," but only if such criticism produces as much furthering of understanding as what is being criticized, and that “pedestrian, routine criticism” is treated as “pedestrian and routine” original research (Longino 77).

Applied to engineering decision-making processes, recognized avenues for criticism of decision-making processes, and in particular the variety of paradigmatic background assumptions used in problem identification and resolution, must be open to critique and reflexive feedback. This can include journals, publications, and conferences of professional engineering societies, but is not limited to only these locations. Due to the public effects of engineering projects, this criterion must also include space for non-engineers to provide substantial transformative critique that engineers encourage and adopt as appropriate. Such avenues should not be considered a space outside of engineering decision-making processes, but a part of the decision-making process itself. Such spaces would allow room for critical dialogue about the paradigmatic background assumptions I listed, and allow for dialog that holds all stakeholders in engineering decision-making processes accountable to substantiate particular viewpoints affecting those decision-making processes. Furthermore, this space would acknowledge that any process of material problem-solving within the world should prepare to revise, critique, and hold tentatively any and all assumptions affecting problem identification, articulation, and resolution.

Shared Standards. For transformative criticism to accomplish anything, communities or sub-communities within scientific practice must have shared standards to evaluate data, evidence, hypotheses and theories (Potter 119). Longino states that community standards can include “both substantive principles and epistemic, as well as social, values” (77). Furthermore, these values may be inconsistent with each other, emphasized differently depending on the situation, and should be held tentatively and open to revision (Longino 77, Potter 119). Even the standard of empirical adequacy may be temporarily suspended or interpreted in different ways, provided it furthers the understanding within a community. The goal of shared standards is to make individual inquirers responsible to something other than themselves (Longino 77).

I argue that the adoption of this criterion among engineering communities would require an articulation of the paradigmatic background assumptions affecting decision-making processes, including assumptions about problem identification, articulation and resolution. Adopting this criterion would also, as in science, articulate how engineers and engineering communities are responsible to those outside of themselves. The extent to which engineering may be held responsible beyond legal requirements is a topic I take up shortly, and I argue that notions of public standards extend beyond what engineers are currently responsible for. This criterion would also require a significant depth in such an articulation, as simplistic notions of what engineering goals rely upon specific definitions and conceptions that need evidential relationships in order to substantiate. By necessity, the articulation of such assumptions would also require engineering fields to clarify assumptions on topics as diverse as market structure, the role of political power, the scope of projects, environmental considerations, macroeconomic viewpoints, ethics, and other topics considered a part of the realm of sociology, psychology, and social sciences that are presented external to engineering.

Community Response and Uptake. Over time, scientific communities are expected to revise or reject viewpoints in response to criticism. Longino points out that this does not imply that scientific practitioners must recant their positions when criticism is brought forth; rather, arguments and ideas may be strengthened by critical discourse (Longino 78, Potter 119). Scientific communities (and members of these communities) must “pay attention to the critical discussion taking place,” and should also “remain logically sensitive to it” (Longino 78). Also, these communities should go beyond simply tolerating transformational criticism, and strive to encourage such criticism, participate in critical dialogue about it, and revise theories in response to warranted criticism.

Adopting this criteria for engineering communities, would require analysis of paradigmatic background features to become central (or as central as empirical adequacy) to decision-making processes, helping address the masked nature of paradigmatic background assumptions as well as the diminished value of those who engage in critical dialogue about such assumptions. This does not mean that all engineers at every point in time would be expected to engage with discussions of paradigmatic background assumptions. Rather, engineers would be expected to remain sensitive to the need to engage and participate in such reflexive discussion as it arises.

Tempered Equality. In order for critical discourse to include all *relevant* perspectives, it is necessary for communities to engage in what Longino describes as an “equality of intellectual authority,” whereby communities of knowers are unable to achieve objective scientific practice if a set of assumptions exist by virtue of the political power of its believers (78-79, Potter 119-120). To include all relevant viewpoints requires communities of inquirers to seek out and encourage perspectives from those communities that may offer critical dialogue (Potter 119). Therefore a failure to include perspectives of groups that have an impact on the critical discourse in a community is actually a cognitive failure, i.e. a failure to include or even try to include the viewpoints necessary to arrive at an objective conclusion.

This criterion will be as applicable to engineering as it is with science, but should be understood in the broadest sense possible. Tempered equality will not be simply about cognitive diversity or the diversity of experiences among engineers. Rather, tempered equality is a process of ensuring a form of diversity that will contribute to uncovering paradigmatic background assumptions that could be analyzed for the presence of idiosyncrasy. Engaging in this process will not inherently guarantee that no idiosyncratic background assumptions are included in engineering decision-making, nor will tempered equality grant permanent legitimacy to background assumptions that emerge from this process. It will, however, provide a framework for who to include critical dialogue about background assumptions in engineering decision-making processes.

In particular, this criterion includes diversity among engineering practitioners or particular engineering fields as well as diversity among all groups that engage with engineering projects – those controlling funding, those designing engineering solutions, those responsible for maintaining or using technology designed by engineers, and those who are affected by the creation, distribution, and destruction of such technology. It should be this broad in order to account for engineering decisions that affect communities outside of engineering, such as future generations, those who were not included in initial decision-making processes, and those who will not receive benefits from an engineering decision, but are negatively affected by such a decision. Global climate change may be a particularly illustrative example of why tempered equality should be interpreted in such a broad sense. Certain engineering decisions – the development of energy-intensive technological systems, the mass production of internal combustion engines, etc. – will significantly affect the communities mentioned above by lowering quality of life, increasing hardship, and negatively affecting those not included in original engineering decisions, for example individuals in low-lying or flood-prone areas, especially those living on small islands whose benefit from such technology may be marginal.

At the end of her description of these four practices, Longino identifies several meta-norms indicating that each of the practices be held: revisable; provisional; in tension with each other and within itself; and with the ability to be withheld under certain permitting, temporary and local circumstances (Potter 120). This should not be interpreted to mean that practitioners of science should hold the four practices or background assumptions that emerge from such practices cynically. Rather, scientific communities should be aware that they may discover that these four practices or the background assumptions arrived at from these practices may not help further understanding, and will need to be modified or discarded – either temporarily or permanently.

Operating in tandem with Longino's four practices, these meta-norms will be able to resolve the tension created by the remaining paradigmatic background assumptions I identified. By understanding that all paradigmatic background assumptions, including those commonly referred to as "facts," operate as mediations between evidence and hypotheses, and that all such background assumptions should remain tentative and revisable, a space is created for a critical analysis of such assumptions in engineering decision-making processes and how (or if) they produce ethically substantial or effective resolutions. Those without evidential support will be identified as idiosyncratic and modified accordingly, or new background assumptions may be discovered that will frame more ethically substantial and effective engineering decision-making processes.

Longino concedes that there are at least three conditions that could or have the potential to diminish the objectivity of scientific communities by limiting critical discourse, failures of the practices and meta-norms listed above notwithstanding. The first arises when criticism of assumptions proceeds for too long and leads to scientific programs that may be interesting, but without connection to empirical practice. Thus, programs such as "creation science" and others that lack empirical adequacy but can fulfill the four practices do not correctly receive attention from scientific communities (Longino 79).

The commodification of knowledge is the second condition, and de-emphasizes critical dialogue of background assumptions in favor of programs that advance but do not question assumptions in data acquisition, interpretation, evidential relationships, etc. (Longino 80). I demonstrated in chapter 1 that a similar lack of attention is given to the study of background assumptions in the operation of engineering decision-making processes in favor of more "productive" (i.e. profitable) endeavors.

A third condition Longino identifies occurs when an entire scientific community holds one (or many) particular background assumptions in common, shielding their recognition or critical discourse of said background assumptions. These assumptions will remain invisible until individuals who are not part of the community provide adequate alternative explanations using alternative assumptions (Longino 80). Historical studies of science demonstrates many such instances where individuals outside traditional scientific communities are able to explain behavior without appealing to established assumptions (e.g. Einstein's theory of special relativity), leading to a shift in paradigmatic background assumptions used by the community. This condition is closely related to my analysis of those paradigmatic background assumptions I felt were held by most engineers, or perhaps by engineers who dictate professional standards and curriculum for engineering. These paradigmatic background assumptions obscure their effects and prevent critical discourse of those assumptions from occurring, as Longino predicts with this third condition.

Longino concludes that some contextual values, operating individually and collectively, are required to produce objective scientific knowledge, and this process is the defining feature of scientific practice. It is possible to examine locations where background assumptions both help or hinder the outcome of research in any scientific community. Ultimately it is not simply the presence of contextual values that determine if particular communities or specific programs are acting in accordance with “good” or “bad” science, but rather how paradigmatic background assumptions are being deployed, and critically analyzed, that determines how objective scientific knowledge could be. I argue that engineering follows Longino's analysis in much the same way.

Import to Engineering

As discussed in the prior chapter, attempts to increase “objectivity” or “empirical adequacy” in engineering are fraught with philosophical and linguistic problems, and Longino's analysis of empirical adequacy, scientific reasoning, and the four scientific practices may seem peculiar to adopt for an applied science with such large somewhat divergent fields such as engineering. In what follows, I add to my analysis of Longino by examining how her method may reduce the tension created by the paradigmatic background assumptions I listed at the beginning of this chapter.

The paradigmatic background assumptions I listed encompass some of the political goods, cultural attitudes, and psychological commitments of engineers and engineering communities. Each has an affect on how engineers order, systematize and structure the world and thus comprise part of the ethical standpoint of engineers. However, these assumptions also stand in tension with each other, as they may cover conflicting goals and ideals, and are not able to guide engineers in how they *should* structure their views of the world while engaging in engineering. As I stated earlier, Longino's method will not directly prove or disprove any particular paradigmatic background assumption, but I argue that her method provides a framework understanding within which engineering decision-making processes will be able to create more ethically substantial and effective resolutions, i.e. solutions that ethically resolve a particular problem without introducing ethical tension in its resolution. By following Longino's call for an adoption of public standards, venues for criticism, a call for an uptake of criticism, and tempered equality.

Engineers will be better prepared to negotiate and articulate paradigmatic background assumptions affecting engineering decision-making, paying particular attention to the reflexive feedback and criticism of communities who are affected by engineering decisions. Such practices will remain flexible for contextual solutions to problems arising from an articulation and negotiation of paradigmatic background assumptions, in the tentative and provisional way Longino holds such practices to be. Her specific call for tempered equality, and my broad interpretation of such a requirement will require mechanisms for the inclusion of local and global participants in engineering decision-making processes, and not simply for technical decisions that affect transnational groups. In the next chapter, I examine some objections toward the adoption of Longino's method, and also attempt to answer questions such as: How can this account create more critical problem seeking and problem resolution among engineers? Can this account be demonstrated to produce more ethical and effective outcomes? How can this account acknowledge the individual action of engineers and the unwieldy social structure and context of engineering? And finally, Does this account produce pernicious moral relativism among engineers?

Chapter 4 – Objections, Applications, Conclusions

Longino's creation of a naturalized epistemology and philosophy of science identifies four practices among scientific communities that are both descriptive, in that they conform to historical examples of successful scientific enterprise, as well as normative, in that they represent how scientific practice *ought* to be. Longino's four practices are:

1. Public venues for criticism
2. Public standards
3. Uptake of criticism
4. Tempered equality

Longino develops her epistemology largely in response to the paradox of bias that feminist philosophers of science encounter when developing normative accounts of scientific practice. That is, if there is nothing incorrect in introducing paradigmatic background assumptions into science, both in the context of discovery and the context of justification, why would anyone presuppose that science using feminist (as opposed to androcentric) values produce better scientific accounts within scientific practice? Longino attempts to reconcile the paradox of bias and feminist philosophy of science by demonstrating that particular non-cognitive values are not inherently pernicious or superior than others; rather what we should expect is that processes within science will provide a space to discuss, revise, reject or embrace such values as appropriate. Her naturalized empiricism and philosophy of science is an attempt to outline such a process.

Engineering, as an inherently moral activity of material problem-solving in the world, is informed and shaped by a variety of paradigmatic background assumptions that affect decision-making processes. These assumptions cover a variety of political goods, cultural attitudes, and psychological commitments, and are designed to operate on the edge of awareness of engineering practitioners. As I argued, Longino's four practices will be useful for analyzing engineering decision-making processes, leading to solutions that include an analysis of the paradigmatic background assumptions exerting influence as well as leading to ethically substantial and effective solutions. Alone, these four practices *qua* four practices do not guarantee substantial or effective problem-solving resolutions. Instead, I argue that these four practices are necessary for *any* substantial and effective resolutions to occur in engineering decision-making processes.

First Objection

The first objection to Longino's method I respond to is that the application of her method is unnecessarily burdensome to engineers and engineering communities for three reasons. First, the amount of time and discourse required by this method is not insignificant; second, historical analysis may demonstrate that engineering decision-making processes have done “well enough” without the need for such a method being deployed; and third, the burden of responsibility on engineers using Longino's method is inappropriate. I will address each reason for this objection in order.

The first feature of this objection holds that Longino's reflexive practices will take a significant amount of time and energy for engineers to implement, limiting the practical amount of time engineering communities have to mediate between individuals and the world. This method does place considerable emphasis on reflexive dialogue between engineering communities and others, not just for a specific project but about technologies in general and the structural functions of engineering communities. The time and energy that will be required in order to articulate an account of paradigmatic background assumptions deployed in decision-making processes might be significant, especially if a technology or project is new or exhibits complex effects. This may include such time-intensive and complex activities as defining common terminology, identifying stakeholders, building consensus, and soliciting a variety of viewpoints and opinions. As a practice of solving material-world problems, it may seem unreasonable to constrain the engineers responsible for designing technological systems – systems that may need to be developed quickly in response to a pressing material need.

Regardless, I do not think this reason provides a legitimate objection, nor does it demonstrate that this is an unreasonable or egregious burden to engineers. Engineers may not need to use Longino's method for every paradigmatic background assumption being used at a particular moment. Once a paradigmatic assumption is acknowledged, and evidence brought to bear in support or refutation of it, there may not be a need to resume discussion with every project making use of that assumption. As with science, particular communities of engineers may benefit from holding a particular set of viewpoints without critical reflection in order to further the understanding or potential applications of a particular technology. Only when new evidence or alternative explanations of evidence arise should such a process be instituted. For example, engineers working on sustainable energy systems – the batteries, transmission lines, and power generation systems to develop wind, solar or hydro power – may hold a belief that such systems will eventually be capable of producing electricity on a wide scale inexpensively. They may proceed apace with development of such systems, demonstrating theoretically and on a small scale how such systems may be implemented, and providing to new directions for further analysis and refinement of such technology. However, when such a system has the potential to produce material impacts related to the assumptions being held without reflection – for instance, determining the economics of large-scale low-density system of power generation – it will be necessary to examine paradigmatic background assumptions deployed during decision-making processes.

Another example may help illustrate. Various engineering programs in higher education have implemented strategies to encourage women and minorities to study engineering and complete engineering degrees. Such programs operate under the assumption that they will lead to higher retention and graduation rates of targeted students. These programs may operate for some time without encountering criticism of the paradigmatic background assumptions used in the deployment of such a program. Only when data are found that calls into question the value of a particular approach – or the value of such a strategy in its entirety – would discussions of paradigmatic background assumptions informing such strategies occur. As with the previous example, it is not that engineers should choose the most well-supported or neutral paradigmatic background assumption to deploy during decision-making processes, but rather that engineering communities remain flexible to challenges toward, and changes in, such assumptions.

As I mentioned earlier, analysis of technological lock-in demonstrates that relatively small or unimportant engineering decisions can produce significant effects in the future and, taken in aggregate with other projects, may produce unanticipated negative effects. It is precisely because of the unintended consequences of engineering projects that leads to my second response to this reason. Complex engineering projects will, due to scale of design, have equally large or exponentially greater impacts on many different groups in the immediate and future. Engineers should account for the ways decision-making processes remain flexible toward future revision of paradigmatic background assumptions used in the deployment of such processes. Without having the ability to articulate how decision-making processes are capable of the type of reflexive action Longino advocates for, engineering is unable to produce ethically substantial or effective solutions to material problems.

The second feature of the first objection to the application of Longino's method to engineering involves showing that historical studies of “good engineering” demonstrate that engineering decision-making processes do not need Longino's method in order to produce ethically substantial or effective solutions to material problems. However, as Longino did by examining the history of science, an analysis of engineering history may instead demonstrate this method as a historically legitimate precursor to substantial and effective engineering decision-making processes. That is, we may observe that instances of “good engineering” in history correspond more or less to Longino's method. Similarly, historical analysis of instances of “bad engineering” may demonstrate that Longino's reflexive practices were crucially missing or absent from decision-making processes.

As I explain later in this chapter, further work must be done in order to demonstrate if my adaptation of Longino's method to engineering is able to account for historical instances of engineering practice. I leave the question open but assume that Longino's method may have correlations in the history of engineering.

The third and final feature to the objection that Longino's method is burdensome to engineers is that it may require an inappropriate level of responsibility for individual engineers who, for the most part, work in the context of complex projects in a corporate setting. As I discussed in my second chapter, engineers in large organizations do not exhibit the level of responsibility or autonomy needed to be held responsible for a decision. Thus in most cases individual engineers cannot be held directly responsible when a part fails, a plan isn't followed, or unforeseen events lead to an engineering failure. I largely agree with this analysis, in that it may be inappropriate for engineers to bear direct responsibility for poor decision-making and the failure of a specific action. However, this limited notion of responsibility for poor decision-making in engineering relies on a paradigmatic background assumption that responsibility is primarily an individual action. I challenge this paradigmatic background assumption and argue that engineers working together *can* be held responsible for how decision-making processes are/were reflexive toward the background assumptions that lead to poor decision-making or an engineering failure. Communities of engineers that incorporate Longino's reflexive practices will avoid this naïve notion of individual responsibility.

Second Objection

Another objection to Longino's four practices questions the appropriate use of the practice of tempered equality. As I articulated in the previous chapter, tempered equality considers illegitimate any community of knowers whose beliefs are held as epistemically valid or invalid solely by virtue of social location or political power. What matters most in objective scientific practice is that situated expertise is valued and sought out. For engineering, decision-making processes have the potential to affect the material conditions of many people, including those who by virtue of social location have no opportunity to object, critique or provide input. I argued that an engineering community following Longino's practice would seek out these voices in a meaningful way, paying close attention to how biases against particular social locations may screen out communities who, in being affected by engineering decision-making processes, should be able to provide input. Given the complex interactions of engineering technologies, including potentially hidden aggregate effects, it may appear that engineering should take input from the entire world, since all persons could potentially be materially impacted by any decision in the future.

However, this objection disappears when we understand tempered equality as a requirement for engineers to be responsive toward criticism and challenges of decision-making processes and paradigmatic background assumptions from affected communities, but *not* the sole seekers of such criticism. Engineers need not poll everyone in the world for their thoughts about a particular technology or engineering project, but must remain aware of and responsive to communities affected by engineering that may not be able to provide criticism because 1) their social location disallows practical engagement with engineering decision-making, and/or 2) their participation is devalued or undervalued when criticism is provided. This awareness must come with an acknowledgment of how power, privilege and difference enable such systems of unsubstantiated epistemic discrimination to continue.

Third Objection

A third objection may arise by the promotion of engineering decision-making processes that are responsive to local, contextual conditions. If engineers are encouraged to consider those conditions that may challenge paradigmatic background assumptions, should an engineer act with moral flexibility to local conditions? For example, textbooks on engineering ethics spend some time discussing bribery, kickbacks, or gifts given in the context of engineering in countries outside the Western world (Schinzinger and Martin 150, Humphreys 43). Scenarios are given as cautionary tales about the ethically ambiguous and confusing aspect of gift-giving. How should an engineer who objects to bribery, but works with a company or government that requires bribes, act using Longino's method? Is it acceptable for an engineer to break or bend his or her ethics in order to conduct business locally? Does this mean all paradigmatic background assumptions, as I have outlined them, are amenable to local rejection, leading to pernicious moral relativism?

I believe paradigmatic background assumptions should not be rejected in response to local conditions, but they may be reassessed globally. If an engineer has well thought-out reasons for assuming that bribery is unethical, it should not be amenable to significant revision without a large body of evidence pointing toward new (or alternative) background assumptions. It is unlikely, but not impossible, for one instance of a local condition to bring about such revision. Only when local conditions provide evidence in favor of global revision or rejection of the original paradigmatic background assumption, *and* an embracement of a different paradigmatic background assumption, should an engineer engage in such processes.

In the example above, an engineer who cynically believes that bribery is unethical will be much more amenable to creating local exceptions. This is not to say that the paradigmatic background assumption of “bribery is wrong” is not valuable. It is because the engineer in question is not saying “bribery is wrong,” but is actually saying “bribery is wrong, but only when I find that it's useful to believe so.” This is not moral relativism, because the engineer in question would not believe that any local culture can do whatever it likes. He or she is merely using an underdeveloped (or perhaps unarticulated) notion of what his or her paradigmatic background assumptions are.

Further Work

Longino examines case studies of scientific practice and argues that her responsive method is historically legitimate, in that it describes how science *has* been done in addition to retaining normative aspects of how science *should* be done. No such work, at present, has been done to examine where the history of modern engineering validates or undermines Longino's method as historically legitimate. Further work to determine how the history of engineering may or may not vindicate Longino's method as both descriptive and normative should be done before engineers fully embrace the four practices. I expect that such an analysis would also identify other practices that may be historically legitimate additions to my importation of Longino's practices in engineering. I also expect that a historical analysis of engineering decision-making will shed light on the types and methods the practice of tempered equality may take. Who should be included, and the forms such inclusion may take, are complex questions that must be analyzed in an engineering context.

As I've mentioned in prior chapters, this thesis is neutral with respect to claims of the evidential support of any particular paradigmatic background assumption, except to note that all such assumptions are a form of ideology that by definition involves some misrepresentation or distortion of the world to a greater or lesser extent. Further work on the assumptions that engineers should embrace, and the reasons for doing so, will become important during the adoption of Longino's method. As with science, I expect that different communities of engineering will have slightly different evidential standards relating to assumptions that may be embraced. Discovering such criteria will be a necessary next step in this process.

Conclusion

Engineering is a process of solving material problems by mediating between individuals and the world, inviting or inhibiting particular perceptions and actions. The particular perceptions or actions that are invited or inhibited are heavily influenced by paradigmatic background assumptions operating in engineering decision-making processes. Furthermore, the mediation of perceptions and actions (or potential actions) by engineering is an inherently moral activity, involving considerations of how we ought to treat each other. Communities of engineers, therefore, ought to consider how to enact decision-making processes that are ethically substantial and effective, i.e. decisions ought to resolve particular material problems without introducing additional problems. Without a framework of decision-making processes that exhibit such behavior, engineering communities will be unable to coherently articulate why they are able to resolve *any* material problem substantially and effectively. Additionally, engineering decisions made without an ethically coherent framework understanding of how to resolve the tension introduced by paradigmatic background assumptions in decision-making processes will lead to solutions that reinforce unsubstantiated hierarchies, under which all are less effective in providing substantial ethical outcomes.

As I argued in the second chapter, a variety of tactics attempt to guide engineers toward particular conceptions of ethics and engineering decision-making processes. These include codes of ethics, pedagogical strategies in engineering ethics, calls for greater objectivity, or an infusion of empiricism into engineering practice. Each of these tactics ignores the tension introduced by intransigent features of engineering that are simultaneously deeply embedded within the social and technical cultures of engineering communities, yet hidden from engineers on the edge of their awareness. These intransigent features cover a variety of political goods, cultural attitudes and psychological commitments toward engineering, the analysis of which is undervalued or ignored by engineering communities.

That paradigmatic background assumptions influence engineering decision-making processes is not at issue; the limitations of classical mechanics have been understood for over a century, but are adequate for daily use by engineers. However, when two paradigmatic background assumptions compete in engineering decision-making processes, how should individuals adjudicate between the two, especially if one or both remain unavailable for critical scrutiny?

Longino describes how scientists adjudicate between competing theories, values, ideas, and beliefs to form what she calls "objectivity" among communities of scientists. She identifies four practices that help legitimize scientific findings as objective, including shared standards, public venues for criticism, critical uptake, and tempered equality. Without such practices, she argues, scientific success will not produce objective accounts of the world.

The work of my thesis has been to examine where Longino's method could produce a fruitful account of the influence of paradigmatic background assumptions on engineering decision-making processes, and assist in creating solutions to material problems that are ethically more substantial and effective. Her method, imported into engineering communities, allows for processes that are responsive to those affected by engineering decisions, and begins to answer the question posed at the beginning of this thesis: what are the attributes of ethical engineering decision-making processes? It is my hope that an engineering community engaged in this reflexive dialogue will be able to produce coherent accounts of ethical decision-making processes that will allow engineering to legitimize its role in solving the material problems of our world.

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