

Virtue Ethics for Applied Scientists and Engineers: Actionable Lessons from Biomedicine

Aris Ozark
mozark@scu.edu

June 2026

Advisor: Guadalupe Hayes-Mota, EngD, MPA, MBA

Completed in fulfillment of the Hackworth Fellowship in Applied Ethics requirements



Santa Clara University Markkula Center for Applied Ethics
Santa Clara, California

Abstract

Existing deontological ethical frameworks for applied science and engineering fields largely fail to guide conduct towards societal flourishing. This thesis argues that Aristotelian virtue ethics better matches traditional approaches to technical problem solving. Virtue ethics is used to create a normative ideal of societal expectation and occupational excellence which can be actively improved over time. Using biomedical ethics as a structural model, an ethical framework for applied scientists and engineers is established. The developed framework consists of five cardinal virtues: prudence, beneficence, solidarity, objectivity, and integrity. The origins and complementary nature of the developed framework is explored using examples in public health and biomedical research ethics. By contextualizing morality as a continuous pursuit rather than meeting a rigid standard of conduct, this framework is poised to align technical decision making towards virtuous ends.

Introduction

It is tempting to designate the work of applied scientists and engineers as morally neutral: that all developed technology is merely a tool to be used for good or evil, or that practitioners should pursue innovation above all else and disregard their moral hesitations. If ethics are to exist in science and engineering, the argument goes, they should be primarily derived from existing deontological or legal frameworks. This sentiment was shared by Enrico Fermi: co-inventor of the first nuclear reactor and chief physicist on the Manhattan Project. Immediately after World War II, Fermi remarked that “I was put on Earth to make certain discoveries, and what political leaders do with them is not my business” (Federation of American Scientists, 1994). Alternatively, consider the cases of the Volkswagen emissions test bypass scandal (Valentini & Kruckeberg, 2018) or the Boeing 737 MAX MCAS design which resulted in multiple fatal incidents (Herkert et al., 2020). In these cases, profound ethical failings resulted from the small contributions of many. Whether the impact is measured in particle emissions or the loss of human life, there reaches a point where the consequences of ethical ambiguity become too great. When the products of science and engineering unlock the capacity to inflict tremendous suffering and destruction –whether intentional or not– its practitioners can no longer claim moral and ethical absolution.

The same is true for those whose work only indirectly contributes to societal harms. For instance, the rapid advancement in electronics technology over the past half-century has indirectly created numerous ethical perils: algorithmic social media, artificial intelligence, mass-surveillance technologies, autonomous drones, and the environmental cost of e-waste to name a few. Only upon post-hoc analysis of downstream effects is the seemingly benign work of chip designers and software developers brought into sharper focus. The technical decisions of how much power an integrated circuit will consume or how an algorithm will serve content have a real moral value. Such cases are incredibly common across the applied science and engineering diaspora: an individual’s work is undoubtedly impactful, but so universal in application and multilateral in practice that one cannot easily discern whether their contribution meets the ambiguous definition of “ethical.” Traditional ethical frameworks for applied scientists and engineers centered around imperatives and obligations struggle to adapt rigid moral reasoning towards problems which are technical and dynamic in nature (Lim et al., 2021), (Pleasant, 2024). In order to engender meaningful discernment and subsequent action regarding ethically-ambiguous topics, a proper ethical framework must be adaptable yet still firmly direct its user toward virtuous ends.

Virtue ethics as pioneered by Aristotle and later Thomas Aquinas contextualizes morality as the proper application of virtuous character traits which straddle vices of excess and deficiency. Conduct is judged within a situation’s context rather than a rigid set of imperatives. Also, great emphasis is placed on the intent and mindset underlying one’s actions. Under virtue ethics, an agent is obligated to pursue ends which strive for greater personal and societal flourishing. In an Aristotelian sense, to flourish means to strive for one’s highest potential and to act with virtue and reason (Kraut, 2022). This definition of flourishing can also be extended towards broader society. This is further exemplified through the concept of *eudaimonia*. To live well and fulfill one’s characteristic function as a rational agent, they must strive for individual and collective flourishing as the highest attainable good (Aristotle et al., 2011). The utility of prioritizing flourishing is that the end-goal is never truly attained.

Rather, the moral agent is in a constant state of self-reflection and improvement. This continuous pursuit of flourishing is in itself a virtuous action. In real-world situations, virtues will invariably conflict with one another, thus necessitating keen awareness and optimization. A similar process of continual parametric optimization is at the crux of the scientific and engineering process. Therefore, virtue ethics can function as a natural extension of the technical problem solving process rather than an incompatible parallel process: when ethical thinking feels familiar, it is more likely to be used.

To strengthen the relevance and utility of virtue ethics for applied science and engineering, the institutional identities of the same will be explored using the Aristotelian concept of *telos*. The *telos* and ethical sensibilities of biomedical science will also be analyzed throughout to adapt human-centric virtue ethics towards other technical fields. The developed ethical framework consists of five cardinal virtues: prudence, beneficence, solidarity, objectivity, and integrity. This thesis does not aim to provide a comprehensive approach to occupational ethics. This would be impractical given the scope of applied science and engineering roles across academia, industry, and government. Rather, the objective is to introduce an actionable, virtues-based ethical framework which empowers individuals to pursue individual and collective flourishing. It is my hope that this work may serve as a foundation for more specific applications of virtue ethics in technical fields moving forward.

Telos of Applied Science and Engineering

Identity is inextricably tied to one's capacity to make decisions. The Aristotelian concept of *telos* stipulates that awareness and internalization of the proper ends and societal expectation of one's profession are both required to act virtuously (MacIntyre, 1981). In occupational ethics, *telos* functions as a normative ideal of excellent conduct worthy of a practitioner's pursuit. *Telos* has both an individual and a broader societal component. For a virtues-based ethical framework, both components are relevant to one another, and both can change over time. It will be useful to clarify the operational definition of applied scientists and engineers and their uniqueness compared to other technical disciplines. All fields under this umbrella use the scientific method, but the traditional epistemic pursuit of knowledge for its own sake is supplemented –and often surpassed by– the pursuit of technical innovation. A distinction must also be drawn between basic and applied science. The former seeks to understand the universe as it exists, while the latter uses the findings of basic research to design novel systems and solve practical problems. The focus here will be on the latter.

At its most basic definition, the practice of engineering involves designing and adapting systems to achieve a technical objective. Complicating a unified approach to ethical discernment is the differing incentives, constraints, and obligations guiding professional and academic engineers. For instance, engineers working in industry may be subject to shareholder obligations, non-disclosure agreements, and employment-at-will pressures among others. Engineers in academia contend with factors such as publication pressure, tenure incentives, and funding obligations. The most relevant distinction between the two disciplines is the degree of choice the practitioner has over the objectives of their work. The influence of these factors are pervasive, and they will necessarily limit the ability of the practitioner to pursue virtuous ends. Even still, regardless of their station it is highly likely that the engineer retains some measure of agency over their approach and methodology of problem solving. It is critical for the practitioner to recognize the scope of their autonomy and seek out opportunities for ethical discernment and virtuous action within the constraints of their position and context.

In any field where the pursuit of innovation and efficiency is the primary objective, ethical consideration necessary becomes secondary. A lack of discernment often prevents the ethically optimal –or most virtuous– solution from being selected. Studies of both engineering students and practitioners show that a primary self-reported reason for pursuing their chosen profession was an interest in the technical aspects of the work (Lim et al., 2021), (Pleasants, 2024). A possible explanation involves institutional self-selection based on social expectation. If the current *telos* of applied science and engineering is currently one with little capacity for ethical discernment and total focus on the technical aspects of their work, then these fields will continue to meet this expectation. The result is a lack of an institutionalized moral identity where societal flourishing is rarely considered. However, since *telos* functions as a normative ideal, it can be modified to include societal flourishing and robust ethical discernment as a part of its identity. The key to reshaping *telos* in this manner may be found in technical fields where humanistic connection is more obvious and foundational to its practice, namely biomedicine.

Biomedical *Telos* and Virtue Ethics

When considering the *telos* and corresponding ethical sensibilities of technical fields, biomedical and public health disciplines present themselves as notable outliers. In addition to being rigorous applied sciences, these fields are expected to have an adaptive, sympathetic relationship with society and to consistently act for its benefit. Their institutional identity is grounded by a direct, tangible duty to an identifiable patient or population: often with life-or-death importance. Under the “ethics of care” framework, virtue ethics within biomedical science—especially for physicians and nurses—emphasizes the underlying motivations, worldview, and context of its practitioners (T. L. Beauchamp & Childress, 2013). It is not enough to pursue virtuous ends; they must be pursued for virtuous reasons. Such reasons are meant to be altruistic and compassionate in nature, and they are intended to care for a patient’s physical and emotional well-being (Held, 2006).

Generally, the *telos* of biomedical science supports an institutionalized approach to ethical discernment which avoids complete moral pluralism (Olivieri, 2018). That said, the development of this standardization was necessitated by many well-documented ethical failings. This is evidenced by cases such as the misappropriation of medical talent in Nazi Germany and Imperial Japan, withheld care and deceit in the Tuskegee syphilis studies, and a wholesale lack of institutional oversight and ethical scruples in the Willowbrook hepatitis experiments. Through public and professional pressure, these missteps brought about meaningful institutional change: for instance, the development and continued refinement of Institutional Review Board (IRB) procedures and board certification (Jonsen, 2003). This is not to suggest that this approach is universally efficacious, but that the role and expectation of biomedical science supports an ethical identity predicated on pursuing virtue and flourishing.

In comparison, the social expectation and corresponding impact of applied science and engineering roles is comparatively diffuse and nonspecific. The only reliable thread of continuity appears to be primarily epistemic in nature (Pleasants, 2024). Yet, a practitioner’s knowledge of a complex technical field does not intrinsically obligate them to pursue virtuous ends. In biomedicine, a *telos* and professional identity whose proper end includes individual and collective flourishing sustains this obligation. Given the substantive differences in *telos*, it is impractical to suggest that biomedical virtue ethics can be entirely adapted to other fields. Rather, this thesis will use biomedical ethics as a model to create a similar obligation within applied science and engineering.

Of the five virtues in the proposed framework, prudence, beneficence, and solidarity are adapted from biomedical ethics. Prudence—the primary faculty of rational, collaborative decision making—is intrinsic to biomedical virtue ethics. Its origins and translatability to other technical fields will be explored. Beneficence is a useful virtue in biomedical ethics because it reframes rules-based morality in positive terms. This allows ethical conduct to be seen as a continuous pursuit rather than a minimum standard. Extending beneficence to applied science and engineering allows for intentional reflection and virtuous action within a moral agent’s context. Solidarity as practiced in public health ethics encourages practitioners to view themselves and their work as necessarily intertwined with the society in which they live. It calls its practitioners to pursue intentional stakeholder engagement and education to inform policy measures. This thesis argues a similar approach to solidarity can assist applied

scientists and engineers in strengthening their understanding of their work's societal effects. Though less explicitly tied to biomedical ethics, the remaining two virtues of objectivity and integrity remain applicable to nearly every field whose methodology is derived from the scientific method.

Despite being influenced by different expectations and constraints, this thesis will argue that aspects of biomedical virtue ethics can enhance ethical conduct in applied science and engineering. The most pertinent and transferable aspects are an institutionalized approach to ethics and a *telos* which supports a continuous, collaborative pursuit of virtuous ends. Crucially, biomedical ethics demonstrates that institutional standards of conduct can be developed and improved upon over time. If *telos* can be directed towards the pursuit of individual and collective flourishing, continuous refinement of ethical discernment becomes more straightforward. This thesis will argue that applied scientists and engineers are capable of doing the same.

Prudence in Discernment and Conduct

In Aristotelian ethics, exercising rational discernment is required for an action to be virtuous. This concept underlies the virtue of prudence: the primary faculty of rational decision making. Aristotle and Aquinas both saw prudence as the capstone virtue, necessary to provide order to an individual's moral and intellectual faculties. More specifically, prudence enables moral agents to discern the ordering and weight of principles in actual scenarios. Since this process is seldom straightforward, prudent moral agents must be able to order facts, principles, and previous experience to maximize their benefit to society. According to Aquinas, the preconditions to prudence are a desire to learn from past experience, a robust understanding of the facts of a situation, a good sense of judgment, the ability to deliberate well, and the capacity to anticipate the wider consequences of a decision (Morales-Sánchez & Cabello-Medina, 2013), (Rest & Narvez, 1994). Especially crucial to prudence is the Aristotelian concept of *euboulia*. This expands “good deliberation” to mean an individual's ability to collaborate well and to recognize their incorrectness in the face of convincing evidence (Hursthouse, 2006). The utility of prudence for this framework is that it guides ethical discernment in a similar manner to technical problem solving and fosters a *telos* predicated on continuous improvement.

In biomedical ethics, a prudent physician must translate professional obligations, technical data, and ethical codes into cohesive action for the benefit of the patient (Olivieri, 2018). Critical to evidence-based medicine is rigorous deliberation with one's colleagues, honesty about an individual's limitations, and a prioritization of patient outcomes (Rogers & Ballantyne, 2010). Prudence is practiced in this manner because the *telos* of biomedicine is beholden to feedback from wider society yet able to sustain a cohesive, institutionalized approach to ethical discernment (Jonsen, 2003).

Although perhaps less familiar with its Aristotelian definition, applied scientists and engineers are well acquainted with rational discernment. The familiar tasks of ordering technical objectives and constraints, collaboration with peers, and learning from previous experience are undoubtedly acts of virtuous prudence. As an example, engineers –whether electrical, mechanical, civil, chemical, or biological– must logically balance constraints such as cost, design time, performance, environmental effects, and longevity in pursuit of some technical objective. Or consider the peer review process in academic science: a practitioner is assailed by criticism and must routinely admit and improve upon the flaws of their research. Thus, an approach to ethics which is rooted in deliberation, nuance, and optimization is *prima facie* compatible with the foundational approach of applied science and engineering.

While necessary for solving technical problems, prudence is by itself insufficient to guide conduct towards individual and collective flourishing. Acting with pure rationality and logic is not conducive to meaningful ethical discernment. What is critical to glean from biomedical ethics is the increased scope of prudence inherent to its *telos*. The goal for applied scientists and engineers must be to extend the deliberative aspect of prudence to include parameters, values, and moral obligations beyond their immediate technical focus. The scope can be extended to include societal effects such as social cohesion, enfranchisement of vulnerable populations, or environmental sustainability. By integrating socially-conscious variables within the scope of prudence in a similar manner to biomedicine, a practitioner's *telos* becomes more receptive to societal feedback. The result is an institutional identity and

ethical conscience more capable of incorporating social considerations into their professional conduct. Prudence is instrumental in synthesizing principles, *telos*, and technical variables into cohesive action, but such a logical approach must be bounded by more than a single virtue. The remaining virtues in this framework –beneficence, solidarity, objectivity, and integrity– are intended to bridge this gap.

Beneficence: The Common Morality and Reciprocity

The common morality is a loosely-defined set of precepts which the vast majority of reasonable individuals are assumed to agree with. It generally stipulates that it is wrong to kill, to wantonly maim or injure, to deprive other moral agents of liberty and autonomy, and to knowingly mislead or deceive (Strong, 2009). These directives are typically framed in terms of nonmaleficence: the obligation to refrain from some negative action. The common morality is not meant to be controversial, rather it functions as a bedrock upon which more comprehensive ethical frameworks may be developed. A nonmaleficent application of the common morality is a useful grounding for deontological approaches to applied ethics and law, but it is by itself insufficient to guide virtuous conduct in pursuit of individual and collective flourishing. To ground an ethical framework for applied science and engineering within the common morality, it is necessary to adapt it in terms of virtue ethics.

The virtue of beneficence is commonly used in biomedical ethics to reframe aspects of the common morality in positive terms. For instance, the nonmaleficent directive to “do no harm” becomes “find and address the root causes leading to harm.” While particular definitions vary across sources, beneficence in biomedicine can generally be distilled to two major concepts (T. L. Beauchamp & Childress, 2013), (T. Beauchamp, 2019):

- Conduct must actively protect and affirm the rights, health, and autonomy of others.
- The practitioner must proactively recognize and mitigate the root causes of harm and injustice, especially concerning the most vulnerable members of society.

Beneficence lends itself well to Aristotelian virtue ethics since its application of the common morality focuses on a continuous pursuit rather than a minimum standard of conduct. A valid criticism of beneficence is that it is highly demanding of moral agents, perhaps excessively so. For instance, one cannot reasonably be expected to proactively respond to every struggle and injustice in the world, nor can they donate all of their income and time to deserving beneficiaries. Such a self-imposed burden is neither productive nor healthy. What exactly constitutes the scope of beneficence –especially within biomedicine– remains an active area of debate (T. L. Beauchamp & Childress, 2013). In this case, the prudent scope consists of pursuing beneficent ends as they pertain to one’s talents and abilities. Beneficent actions which are focused and relevant to a practitioner’s context are more likely to be effective.

For many fields in applied science and engineering, the human-centric ramifications of their work are not immediately obvious. As such, an otherwise well-intentioned practitioner may disregard their work’s connection to the common morality as irrelevant. Realizing beneficence as a virtue requires a moral agent to reject this abdication of responsibility and actively seek beneficent applications of their work if none are readily apparent.

The principle of reciprocity can also be used to engender a greater disposition toward virtuous beneficence. A society’s collective physical and intellectual upbringing of a practitioner in a complex field is undoubtedly an act of beneficence deserving of recognition. Reciprocity should not be thought of as a debt of obligation, rather it is a deeply-held inclination towards gratitude. Ideally, this manifests as using one’s talents directly in service of socially beneficial ends. A clear instance of reciprocity exists within medicine: the donors

for cadaver-based learning and the patients who provide an ongoing source of learning all constitute beneficent acts worthy of gratitude (T. L. Beauchamp & Childress, 2013), (Olsen et al., 2007). Though perhaps less obvious, a similar process of reflection and gratitude can exist for fields outside biomedicine. For instance, gratitude can motivate one to consider how to best care for the institutions responsible for their education, to consider how their work will affect the intellectual well-being of broader society, or to inspire and educate future generations. This discernment process is further aided by the virtue of solidarity, a connection which will be explored in subsequent sections.

Grounding this framework within the common morality allows for a practitioner to more capably pursue societally-beneficial ends. Beneficence in biomedical ethics is transferable to other fields because it encourages intentional reflection and active pursuit of the common morality. For practitioners where beneficent applications of their work are difficult to discern, the principle of reciprocity compels them to feel gratitude towards society and critically discern ways their work and abilities may translate to localized, beneficent action.

Solidarity: Lessons from Public Health

It has been established that aspects of biomedical virtue ethics readily extend beyond their target disciplines to enhance ethical discernment in non-medical applied science and engineering. Continuing with this theme, public health extrapolates many of the same principles of the patient-physician relationship towards broader society. The goal of public health is to improve the well-being of a large population by directing collective, large-scale interventions (Grill & Dawson, 2017). Core to this is the virtue of solidarity, in which one actively seeks kinship and accountability across all members of the human species and natural environment (American Public Health Association, 2019). Scholars of virtue ethics emphasize the inseparability of individual and collective flourishing through the concept of *zoon politikon*: an individual must meaningfully and continuously interact with society in order to make themselves virtuous. Through this interaction, one can learn the best ways to apply their talents for the common good (Martins, 2019). The virtue of solidarity as practiced in public health ethics offers a useful example for applied scientists and engineers to view their work's connection to society writ large. This connection offers two core utilities: solidarity creates a more scientifically-literate and flourishing public, and it allows a practitioner to better discern the merit and possible harms of their work. This section will introduce the virtue of solidarity as well as its vicious extremes. Public health ethics will also be used to strengthen the relevance of biomedical virtue ethics for applied science and engineering.

The most useful axis on which to measure the virtue and vices of solidarity is public connectivity and engagement. The deficient vice of solidarity is disengagement with the societal effects of one's work. This can manifest as a disregard for civil debate about the risks and benefits posed by certain technologies or minimal efforts made to engage in public education. Conversely, the vicious extreme of solidarity is realized when one assumes paternalistic control over the public interest. In Kantian terms, paternalism over rational agents is a violation of their humanity (Kerstein, 2024). In public health, this would constitute an overreach of authority where the reduction of civil liberty and individual agency is not matched by a commensurate increase in public safety (Bhuiyan, 2025).

Public health practitioners must translate emerging, technical information into actionable messaging and policy. There exists a difficult tension where a practitioner's knowledge of a technical field affords them an implicit "intellectual authority" where they are directly responsible to inform public opinion rather than coerce it. Without solidarity, one can struggle to connect with laypeople to whom the merit of public health interventions are less obvious. This disconnect can prove corrosive to trust in essential public health institutions and to science more broadly (Niederdeppe et al., 2025). To avoid this outcome, virtuous communication must be intended to complement an individual's decision making rather than augmenting or supplanting it.

In a similar way to public health policy, the products of applied science and engineering will inevitably draw public skepticism. They present new and unusual risks, bring about social and economic upheaval, or simply run contrary to conventional wisdom. When practitioners take no part in mitigating risks or fostering unpretentious and unclassified dialogue, skepticism readily turns to mistrust (Milkoreit & Smith, 2025). When advancements in science and technology are not competently communicated nor commensurate with the public good, trust in its practitioners is neither possible nor deserved. To effectively realize the

virtue of solidarity and act in the public's best interest, applied scientists and engineers must engage with and inform the public on the methodology, novel findings, risks, and benefits posed by their fields. Such efforts must also be culturally relevant and receptive to public skepticism.

A noteworthy example of effective communication is the public health response to the American HIV/AIDS crisis in the 1980s and 90s. Early efforts to mitigate the crisis were actively hampered by federal inaction, a lack of well-funded research to inform messaging, and persistent bigotry toward vulnerable communities (Padamsee, 2020). Lacking top-down institutional support, grassroots organizations were critical in shaping early messaging and response strategies. Former director of the San Francisco Department of Public Health, Mitchell H. Katz, discussed the importance of this "culturally competent" approach undergirded by engagement with stakeholders and affected communities (Katz, 2005). His department, followed by many others, used this ethos to create practical communication and risk mitigation strategies. These included frank guidance on safe sex, how HIV could and could not be transmitted, and fighting stigma by showing what living with the disease looked like (U.S. National Library of Medicine, 2021). In this case, individual solidarity was required in the absence of procedural, rules-based guidelines. The success of their efforts hinged on the competent dissemination of actionable, empathetic, and relevant information.

For engineers and applied scientists—professions where individual virtue must often guide ethical behavior—this case offers several pertinent lessons. Firstly, good-faith efforts must be made to understand the concerns, perspectives, and beliefs of layperson stakeholders. This enables the development of scientific literacy on the part of the layperson and critical reflection by the practitioner as to whether their work contributes or detracts from collective flourishing. Secondly, useful and unpretentious communication must actively shun unobjective partisan politics and patronizing appeals to moral, religious, or intellectual superiority. To do otherwise only deepens mistrust.

Education on the critical intuition, societal implications, and takeaways for laypeople are possible for any technical field. The prudent application of this is both subtle and dependent on the practitioner's field. Nevertheless, a generalization of the approach to communication shared by effective public health campaigns and successful scientific communicators yields an actionable framework (Sagan, 1997), (Phillips, 2013), (Xia, 2023), (Katz, 2005):

- Careful effort must be made to avoid jargon, pedantic language, and ineffective or inaccurate analogy; simplification cannot come at the cost of accuracy. Finding a prudent balance between the two requires both practice and a deep familiarity with the topic at hand. Also, far more important than specific findings and jargon is effective communication of intuition, tradeoffs, and the methodology of science and engineering. Borrowing from language of informed consent in medicine, an adequate understanding need not be a complete one (T. L. Beauchamp & Childress, 2013).
- The communicator must hold an active empathy with, and understand the context of, those they are educating. They must remember the ignorance they once felt, which topics are particularly difficult to understand, how relatable analogy may be employed, and meet mistrust and skepticism with patience and grace.

- While less tangible, also critical is a closely-held Kantian belief in the intrinsic rationality, intelligence, and curiosity of humanity (Kerstein, 2024). This imbues the communicator with a certain resolve as they will believe their efforts to be more meaningful. This aspect also affirms solidarity: the communicator is helping rational agents come to a more complete understanding rather than assuming paternalistic agency over their opinions and motivations.

Public health offers a useful example for extracting critical concepts and insights from technical research and publicizing them. Realizing the virtue of solidarity requires that applied scientists and engineers actively popularize the methods and core concepts of their field. This enables the public to be better informed of the risks and benefits posed by advanced research and technology. Such efforts must be “culturally competent” and strike a balance between simplicity and accuracy. Crucially, they must not assume undue agency over the beliefs and interpretations of the public. Human connection also encourages the practitioner to discern whether their work supports the public’s best interest. Putting names and faces to the societal effects of one’s work engenders a state of reflection which would otherwise be absent. Through diligent and collective engagement, solidarity fosters accountability: with it, deserved public trust and a self-correcting *telos*. Thus, solidarity as practiced in public health ethics is indispensable to the virtuous practice of applied science and engineering.

Scientific Objectivity

The practitioners of applied science and engineering are, like all humans, vulnerable to bias, tribalism, and unobjective distortion of the truth. Although extraordinarily capable, our sensory biology and intellectual faculties are both imperfect. The individual's ability to competently and responsibly conduct advanced research and development is therefore intrinsically limited. Science and engineering are tools which humans use to strive for objectivity despite our tendency toward the opposite. Leveraged properly, they enable the creation of societally-beneficial knowledge and ways of solving problems. Both methodologies owe much of their influence to the Enlightenment-era philosophies of rationalism and empiricism as pioneered by René Descartes and Francis Bacon respectively. Rationalism stipulates that ideas must be falsifiable and that science must treat all claims with both skepticism and humility (Descartes & Moriarty, 2008). Empiricism adds that scientific findings must be rigorously deduced through experimentation, evidence-based analysis, and Newtonian construction from first principles (Bristow, 2023). These ideals combine to form the virtue of objectivity.

Modern philosophers of science often explain scientific objectivity in terms of the Value-Free Ideal: the belief that practitioners should strive to eliminate the impact of contextual and personal biases on scientific reasoning (Reiss & Sprenger, 2020). However, I contend that virtuous objectivity cannot realistically be practiced in a purely Value-Free or empirical manner. No act of intellectual curiosity –to say nothing of a lifetime devoted to a particular field– can nor should be separated from the beliefs and motivations of the practitioner. The everyday work of applied scientists and engineers is often undergirded by a deeply subjective, impassioned motivation. A measured amount of subjectivity drives individuals to uniquely contribute to their chosen field. Nevertheless, there remains a critical caveat: it cannot be overstated that scientific research guided by unchecked conviction and ambition tends to fall into error, often gravely so. For passion and ambition to be in service of individual and collective flourishing, they must be balanced with impartiality, skepticism, and consensus with one's peers. However, total intellectual objectivity characterized by disengagement with both context and conscience is similarly dangerous. To realize objectivity as a virtue, a practitioner must strive for the mean between passionate conviction and detached neutrality.

In isolation, strong personal convictions are insufficient to guide virtuous decision-making. Especially vulnerable are emerging areas of research and work carried out in secrecy. A worthwhile example of both can be found in the case of He Jiankui and the first known instance of human germline editing. The technique refers to genetic alterations made in the earliest stages of embryonic development. Unlike traditional gene therapy, which modifies specific cell types in highly localized areas, alterations made in germline editing will be reflected in every cell of the subject's body and their offspring's *ad infinitum* (Greely, 2019b). Conducting the procedure in humans is ethically dubious in part because it precludes traditional notions of informed consent and autonomy. In theory, the correct alterations could eliminate any manner of heritable disease, but this assumes an understanding of the genetic code that simply does not –at present– exist. Given the uncertainty and risks involved, the 2018 Nuffield Council on Bioethics called for a prudent moratorium on human germline editing until such a time as the biological, legal, and moral implications could be better understood (Nuffield Council on Bioethics, 2018).

Later that same year, He Jiankui, a prolific young professor at Shenzhen Southern University of Science and Technology, announced that he had performed germline editing on two human embryos: allegedly disabling a major pathway of HIV infection. The experiment was performed without IRB approval, with questionable informed consent by the parents, and with no meaningful consultation with the broader scientific community (Greely, 2019a). Upon the birth of the twins, He unexpectedly presented his research at the 2018 Human Genome Editing Summit in Hong Kong. When confronted about the ethical and procedural insufficiencies of his experiment, He appeared confused and irritated by the negative reactions he received: largely shirking questions and criticism (Jiankui, 2018). Following the conference, He faced widespread condemnation by the scientific community, was fired from his faculty position, and was imprisoned for the illegal practice of medicine (Engineering & of Sciences, 2019).

For his part, He cast his work in beneficent terms: the procedure showed “mercy” by preventing “a lifetime of suffering” (The He Lab, 2018). Whether the experiment was primarily motivated by ambition or perceived beneficence is, for the sake of this argument, irrelevant. Regardless, it is apparent that He held an overriding conviction of the righteousness of his work. He expected that his unilateral, impassioned approach to applied science would earn him respect and recognition. In a retrospective, Henry T. Greely –a law professor at Stanford University– interpreted the case of He Jiankui as a failure of the scientific community to regulate itself. Both the secrecy of the experiment and the convictions held by He prevented objective discernment from taking place (Greely, 2019a).

Returning to the concept of *zoon politikon*, a singular agent is not likely to act virtuously in the absence of consultation and deliberation with their peers (Martins, 2019). In more practical terms, the tendency of individuals to over-estimate their own judgement and sense of moral righteousness are both well-documented features of the human psyche (Yaniv & Kleinberger, 2000). Also worth briefly mentioning is the potential role of formalized professional societies to encourage objectivity through consensus. However, this presents an opening for tribalistic conservatism or groupthink to either stifle innovation or lead to wholesale support of unethical research. While a prudent middle ground may well exist, it is outside the scope of this piece. In the near term, for applied science and engineering to regulate itself as a collective, its practitioners must first learn to regulate themselves as individuals. The burden of humility falls squarely on the practitioner to recognize their own biases and convictions which may lead them to reject counsel and deliberation.

Even in cases where overriding personal convictions are absent, the perils of the secrecy culture must also be addressed. For large swaths of the applied science and engineering diaspora, the technical details of their work –and the risks presented by them– are entirely hidden from public scrutiny. The focus here is primarily on roles in industry and government: the nuclear scientists, semiconductor engineers, pharmaceutical researchers, and product designers whose work drives many of the most ethically-perilous fields in the present day. While some justifications for secrecy may have merit, be it for national security or intellectual propriety, the difference between prudent confidentiality and deliberate moral obfuscation can be difficult to discern, especially from within. The societal risks of advanced research and development may not be easily recognized nor mitigated without open and unobscured public consideration (Sagan, 1997). When valid objections and inquiry are hindered by bureaucracy, powerful financial interests, and legally-binding secrecy; when opaque language

and fragmentation prevent even the practitioners from understanding the issues at hand; when prudent whistleblowing becomes difficult or dangerous; the ability of science to effectively regulate itself falls apart, as does the ability of applied scientists and engineers to act objectively. To work within the secrecy culture is to devote oneself to another's convictions rather than their own. In order to maintain personal objectivity, it is critical for the practitioner to exercise their personal agency and reflect on the purpose and validity of their work being kept confidential. Justified secrecy is more likely to take the form of application-specific designs and procedures rather than entire areas of research which would traditionally require stringent IRB or regulatory approval. Absent the safeguards of objective discernment, it is unlikely that research and development carried out in total secrecy can be commensurate with individual and collective flourishing. Given the risks posed by modern science and technology, the standard for objective, skeptical, and unfettered inquiry by the scientific and engineering communities –and from the public via democratic institutions– must be incredibly high.

Virtuous objectivity in applied science and engineering is not an individual achievement. Finding a balance between intellectual detachment and personal conviction is only possible when a practitioner has the humility to seek collaboration: to submit themselves and their work to good-faith and unobstructed scrutiny. A culture of secrecy, whether personal or institutionalized, is *a priori* driven by unobjective conviction and is altogether corrosive to the multilateral nature of virtuous objectivity.

Intellectual and Vocational Integrity

Integrity is best introduced by its definition outside of applied ethics: something possesses integrity if it is complete, healthy, or otherwise structurally sound. In virtue ethics, integrity requires not only truthful conduct and logical consistency, but the integration of incentives, motivations, worldviews, and virtues into coherent action. A practical example of this idea can be found within pedagogical theory for medical education: practicing integrity in medicine means honoring the implicit trust placed on a physician by society. This endeavor is aided by the comparatively unabstract nature of their goal: doing their utmost for the patient in their care (Rogers & Ballantyne, 2010). The *telos* of applied scientists and engineers affords them with a similar implicit trust, though with a less clear path towards honoring it. Aligning this obligation to society with everyday technical decision-making constitutes a rather challenging optimization problem. Maintaining integrity, then, becomes a continuous pursuit rather than a minimum standard of conduct.

For the purposes of this framework, integrity does not cleanly fit between two vicious extremes. Rather, it is beneficial to view integrity as the pursuit of intellectual and vocational intactness. The ideal of intellectual integrity requires adhering to a role’s *telos* despite external pressures to betray it (Cox et al., 2025). In applied science and engineering, this is most clearly evident in cases of academic fraud and professional misconduct. Vocational intactness refers to a deep respect of one’s own agency, beliefs, morals, and worldview. For one’s work to meet this standard, they must learn to stand for something worthwhile (Calhoun, 1995). By recontextualizing one’s work as being in pursuit of a higher-order goal, apathy regarding the societal effects of one’s work becomes morally impermissible.

The clearest application of integrity with respect to applied science and engineering is the ideal of intellectual honesty. Fabricating or misrepresenting experimental data, denying the counsel of colleagues and impartial third parties, and unobjective interpretation of results all constitute violations of integrity. These actions are detrimental towards societal flourishing by betraying trust and sidestepping prudent, objective pursuit of virtuous ends. Inspecting cases of epistemic misconduct among scientists and engineers shows that intentional malice is not a necessary precondition to a breach of integrity. Dr. David Goodstein, former Vice Provost of the California Institute of Technology, was responsible for investigating and adjudicating cases of misconduct at the Institute. From his experience, he outlines three major conditions present in most violations of scientific integrity (Goodstein, 2010):

- The practitioner is under considerable pressure to deliver results. Most often they are early in their careers and have limited oversight or engagement with their peers.
- The practitioner earnestly believed they knew the conclusion before the evidence had been collected. Rashness and credulity combine in this case to make a practitioner vulnerable to impassioned violations of integrity.
- The practitioner is working in a field where independent reproduction is not easily achieved nor expected for a result to be accepted. In fields such as semiconductor technology, initial failure to reproduce a questionable result can easily be attributed to operator or equipment error rather than a physical impossibility (Service, 2002).

These preconditions provide a useful bellwether for applied scientists and engineers. Continuing to practice within these circumstances opens a practitioner to violations of integrity, whether they intend to do so or not. To maintain epistemic integrity, a practitioner must possess both situational awareness and hold strict adherence to objectivity and collaboration.

The most elusive and crucial task in maintaining integrity is the concept of ideological intactness. This refers to the alignment between one's work and beneficent ends. Biomedical virtue ethics excels at this because of its clear connection between technical science and a humanistic good. In order to develop a similar vocational identity, applied scientists and engineers must first connect their work with some higher-order objective. Discerning, applying, and maintaining this alignment is not trivial, and it will look different for every individual. Also crucial to maintaining integrity is solidarity: the practitioner must actively engage with stakeholders to ensure alignment between their work and the public's well-being. When a practitioner holds a deep commitment to a worthwhile goal, they are more likely to confront unjust aspects of their work; they are more likely to honor their own sense of moral righteousness and pursue beneficent ends. Realizing vocational integrity constitutes a wholehearted embracement of one's unique perspective and identity. When combined with the other virtues in this framework, everyday conduct will begin to align with individual and collective flourishing.

Conclusion

Virtue ethics is perhaps a less definitive approach to occupational ethics than deontological or legal frameworks, and this thesis does not pretend to undermine their legitimate utility. For applied scientists and engineers, reframing morality as a context-dependent ordering of principles allows ethical discernment to naturally fit within traditional technical problem solving. Also, prioritizing the improvement of *telos* challenges practitioners to continuously strive for virtuous ends and act for the benefit of society. Biomedicine was chosen as a structural model for this framework because of its similarly technical nature and its reliance on adaptive *telos* as a means to create an institutionalized ethical identity. Despite substantive differences in practice, influences, and systems of accountability both organized and informal, a similar virtues-based approach to ethics can be realized in other fields.

Binding every virtue in this framework is prudence; a prudent practitioner is able to order virtues and technical objectives towards societal flourishing. Beneficence enables a practitioner to connect their work to a continuous pursuit of the common morality. Moreover, the principle of reciprocity allows one to be motivated by a deep sense of gratitude towards broader society. This connection is further aided by the virtue of solidarity, enabling a practitioner to meaningfully engage with and educate broader society. Solidarity also allows a practitioner to discern whether their work is commensurate with the public's best interest. Objectivity explicitly unites virtuous prudence with scientific inquiry. It empowers a practitioner to contribute to their field with passionate drive, yet temper their ambition with open collaboration, skepticism, and humility. Although integrity and prudence appear to overlap, the critical distinction is that the latter seeks to order principles towards a higher-order objective beyond the self. By doing so, a true vocational identity predicated on pursuing virtuous ends can be realized. Expanding on the concept of virtuous integrity, future research should aim to further explore the process for discerning and maintaining a higher-order objective as the focus of one's work. Also valuable would be analysis on the applicability of this framework to specific occupations and possible conflicts with existing professional guidelines.

Critical components of modern society depend on the unique training and skills of applied scientists and engineers. Nevertheless –as is usually the case– with great power comes an equally great ethical responsibility. Given the risks posed by modern science and technology, an abdication of moral accountability is no longer a justifiable position. Regardless of their role or professional context, an individual practitioner has tangible agency to pursue virtuous ends. A future is possible where, realizing their collective influence and responsibility, practitioners work to instill a *telos* predicated on the pursuit of societal flourishing and robust, broad-based ethical discernment. Whether applied scientists and engineers can rise to the challenge of creating this future is entirely dependent on their own volition: a disquieting yet deeply empowering proposition.

Acknowledgements

I want to extend my heartfelt gratitude to my advisor and mentor Dr. Guadalupe Hayes-Mota. His encouragement, counsel, and genuine care throughout this fellowship have been invaluable. Also deserving of thanks is Dr. Susan Kennedy in the Department of Philosophy for her initial recommendation and advice as I prepared my application for the Hackworth program. At the Markkula Center, I want to thank Dr. David DeCosse for his support and for facilitating many meaningful ethical discussions. I am also indebted to my co-fellows in this year's Hackworth cohort; thank you for inspiring me with your projects, challenging me to critically examine my own ideas and ethical stances, and providing such a positive community. In particular, I am grateful to Sahana Kumar and Sahana Chandramohan for their feedback on my thesis as fellow engineering students. For their administrative and technical support, I thank Johana Engstrom and Debbie Dembecki. Lastly, I thank my family and friends for their support, patience, and unwavering faith in me.

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