The relationship between philosophical traditions and engineering is complex. At any one time in a single culture, a number of philosophical schools vie for attention—even in ancient Greece, the Neoplatonists, Aristotelians, and Stoics offered different ways to understand the world—and various perspectives arise within each school. These variations multiply over time, and the influence and purchase of different philosophical perspectives ebbs and flows.

Engineering is also multiple: the term can refer to engineering practice, its social institutions, or a way of thinking about the world. The practice of engineering is the design, development, and maintenance of sociotechnical systems for the production of services, systems, and artifacts (collectively, technology), and, for the latter, their decommissioning, guided by mathematics and the physical and engineering sciences (see Chapter 1, “What Is Engineering?” by Carl Mitcham, and Chapter 5, “What Is Engineering Science?” by Sven Ove Hansson, this volume). Engineering practice today normally takes place as part of a technically challenging project that is part of a collective or joint venture involving a myriad of agents. The practice is explicitly defined through the creation and publication of standards, codes, and best-practices; it is implicitly determined by customs and traditions that are passed along to new engineers as they learn how to contribute to projects (see Chapter 54, “Engineering Practice From the Perspective of Methodical Constructivism and Culturalism” by Michael Funk and Albrecht Fritzsche, this volume). Engineers are often asked to assess uncertainty and manage risk, weigh various values, and take into account the interests of a variety of stakeholders affected, either directly or indirectly, by their projects. The social institutions of engineering are shaped by the roles that engineers occupy within their organizations and the socioeconomic structures in which they work, characteristics of the educational system that produces these engineers, and, in some cultures, their self-organization in professional organizations. More generally, engineering can be thought of as a way of thinking or a way of life, i.e., one in which human activity is always a form of problem-solving, especially as it employs quantitative methods and technological innovations. Engineering, in each of these forms, also advances over time.

Engineering practice and its social institutions, much like practice and social institutions in general, are products of a myriad of influences, including historical traditions, education, ethical beliefs, politics, religion, available technologies, and media. They have been in dialogue, as it were, with influential philosophical ideas that have varied between cultures, and even within one culture, over time.

While engineering is not yoked to one philosophical school, contemporary engineering practice is closely connected with modern technology and modern science, on which it depends and to
which it contributes (see Chapter 5, “What Is Engineering Science?” by Sven Ove Hansson, and
Chapter 6, “Scientific Methodology in the Engineering Sciences” by Mieke Boon, this volume).
Modern technology and modern science provide common practical and epistemic elements regard-
less of where practice takes place today, though assessments of their importance and fundamental
nature vary. At the extreme, in the 1950s and 1960s, Martin Heidegger (1993) finds these elements
determinant in his influential analysis of the reductive nature of modern technology, which draws a
direct lineage from ancient Greek foundations to its present culmination. More commonly, analyses
of engineering practice show that much of it is sensitive to local values, though modern technol-
ogy and science offer a critical inflection point in the historical development of artisanship. In spite
of more than two thousand years of Greek and Roman influences, the technology developed from
engineering practices, its adoption, and its cultural impact varies across the “West” in their develop-
ment and their acceptance. Differences are further brought into relief in contrast with non-Western
cultures, where the development of modern engineering can be traced to an infusion of modern
science and technology into traditional artisanship and epistemic practices. As an example, based on
a historical, anthropological, and linguistic analyses of this transformation in China, Qin Zhu (2010)
shows that important residual elements of earlier technological practices and an orientation toward
social benefit differentiate Chinese engineering from its Western permutations, which he sees as
more closely yoked to its military heritage and capitalist goals (see also Chapter 4, “Eastern Philo-
sophical Approaches and Engineering” by Glen Miller et al., this volume).
Perhaps these complexities have been impediments to the development of a more thorough under-
standing of engineering and various philosophical traditions. Technology has been called “the path
between philosophy and engineering” (Mitcham 1994), yet the path has rarely been fully traversed.
The voluminous literature about philosophy and technology rarely extends to engineering; most philo-
sophical investigations of engineering are narrow, often emphasizing technical know-how, processes, and
decision-making techniques, at the expense of considering its place in broader philosophical traditions.

In this chapter, I sketch out some connections between engineering and several well-known
Western philosophical traditions. My approach overlaps slightly with Carl Mitcham and Robert
Mackey’s (2009) foray into the space: they briefly describe six different approaches to philosophy
of engineering—phenomenological philosophy, postmodernist philosophy, analytic philosophy, lin-
guistic philosophy, pragmatist philosophy, and Thomist philosophy—before focusing on the linguist-
ic approach. I proceed in roughly chronological order starting with Aristotelian philosophy and
the ethical framework developed from it, virtue ethics. Next I turn to Immanuel Kant’s systematic
philosophy, which yields important epistemological insights and a different approach to ethics based
on duty, which I supplement with the prima facie duties of W.D. Ross. Then I consider consequential-
ist theories that are more empirically oriented, especially the utilitarian theories of Jeremy Bentham
and John Stuart Mill, along with the proto-utilitarianism of David Hume. At the end of the section,
I turn to the pragmatist tradition, which has many familial resemblances with utilitarianism and an
engineering view of the world.

3.1. Aristotelian Philosophy and Virtue Ethics
Using an Aristotelian framework to analyze contemporary engineering indulges in an anachronism:
the natures of craft and knowledge known to the ancient Greek and medieval philosophers differ sig-
ificantly from what is taught at engineering schools today. Both precede the development of mod-
ern experimental science, which takes its form in René Descartes’s method, described in his 1637
book Discourse on Method (2007); Francis Bacon’s instrument-based epistemology, described at length
in The New Organon (2000), originally published in 1620; and modern mathematics, including cal-
culus and differential equations. The elements of modern technology that Hans Jonas (1982) thought
made it a suitable topic for ethics—its transformation of human activity, the subject of ethics, in kind,
not just in degree, by working at a more fundamental level, with dramatically increased power, with effects that last far longer, and with a much higher level of uncertainty—were not present in earlier periods. Moreover, the influence of Aristotelian and related philosophical schools waned in philosophical circles during the period in which modern engineering and its societies came into being.

Yet important aspects of Western culture, technology, and engineering can be traced to the ancient Greeks. The Scholastic influence, most importantly Thomas Aquinas (1225–1274), provided a ground for cultural development that can integrate religious revelation with Platonic and Aristotelian thought, and its influence is shot through Western culture today. More recently, the renewed interest in virtue ethics in philosophical circles beginning in the 1960s spread to professional ethics, especially bioethics, whose problems arose largely because of technical interventions, and recently has been extended to engineering ethics. C. E. (Ed) Harris (2008) has argued that virtue ethics provides a framework in which dispositions toward nature, attunement toward risk and the social context of technological change, and commitment to the public good can more easily be expressed; it also emphasizes the discretion, judgment, and commitment that recede into the background in other theories. Along similar lines, Jon A. Schmidt (2014) has argued that that ethics in engineering is expressed in the accepted practices and common habits of engineers, which aligns with a virtue ethics framework.

On account of its comprehensiveness and its foundational influence on later philosophers, Aristotle’s philosophical system, which includes ontology, epistemology, politics, logic, and ethics, is the best starting point to investigate engineering, and, of these areas, the most fitting departure point is ethics, understood as the study of free human behavior. Working off a definition of virtue (arête) as whatever makes a thing an excellent specimen of its kind, Aristotle (384–322 BCE) offered a new definition for the term eudaimonia (often translated as happiness or flourishing) as the end that all humans ought to seek by their nature. Eudaimonia is being in accordance with articulate speech and reason (logos), i.e., acting in accordance with virtue (Aristotle 2002). Human virtues can be divided into two categories. Intellectual virtues (or virtues of thought) are gained through instruction and experience, whereas moral virtues (or virtues of character) are gained through repeated and intentional action that “ingrains” particular habits into our being. A virtue is a mean between deficiency and excess. For intellectual virtues, one can err in excess by affirming truths that are not present and by deficiency by denying truths, i.e., through incoherence between what is and what one thinks. For moral virtues the error is found in disposition and act, e.g., the deficiency of courage is cowardice and its excess is rashness, although some dispositions, such as envy, and some actions, such as murder, are always vicious. While all humans by their nature should seek the moral virtues, the way they express themselves differ for individuals, and individuals have tendencies to err toward one extreme or the other.

The intellectual virtue most directly related to the practice of engineering is techne. It is craft know-how or knowledge of the art of making, a stable capability that a person can possess over and above particular understanding of how to make a specific object. Those who hold it know how to best bring about a desired outcome, which depends on an appropriate assessment of contingent conditions. Techne operates on contingent beings, especially the material stuff of the world: in this way, it differs from other virtues, because its activity results in the modification of the world outside the agent, whereas the other virtues primarily result in a modification or a shaping of the agents themselves. Aristotle considered techne a productive art, subordinate to higher ends, which was ultimately political, i.e., having to do with the welfare of the polis.²

Like techne, the intellectual virtue phronesis (prudence, practical judgment, or sometimes practical wisdom) is also concerned with contingent beings, though in this case the virtue is properly assessing a particular situation to determine the proper or good (i.e., beautiful, useful, and pleasant) act for a virtuous agent. It is called the queen of the virtues because all of the virtues depend on it. It serves as a bridge between virtues of thought and virtues of character. As one of the cardinal virtues, it directs
courage, the ability to work against one’s fear; temperance, the ability to moderate one’s inclination or desires; and justice, the fundamental political virtue that is most simply defined as giving each his or her due.\(^3\)

The remaining intellectual virtues have as their object that which cannot be otherwise; they are purely intellectual. Episteme (intelligence) is the process of deductive reasoning, which can be hypothetical, from principles to necessary conclusions, an act that is often connected to the kind of reasoning found in sciences. It is always employed in techne.\(^4\) Nous (understanding) is the grasping, immediately or inductively, of fundamental truths or principles.\(^5\) Sophia (wisdom) is understood as episteme and nous ordered toward their highest and best ends.

The virtues align with many aspects of the practice of engineering. The physical processes of engineering, which operate over contingent objects, are connected most closely with techne, though the dependence of modern engineering on the natural and engineering sciences, on mathematics, and on abstract reasoning, in particular in the processes of modeling, emphasizes its interactive relationship with episteme. The actions of an engineer in bringing about these processes depends on phronesis, which includes cleverness, or reasoning well from ends to means. These three virtues come together in engineering judgment, which includes self-assessment of competence, risk assessment and management, and how to appropriately respond to a myriad of concerns and interests. Phronesis allows an engineer to recognize conflicts of interest, and the virtue of justice is necessary to respond appropriately in these situations. Working well within the complex organizations in which engineering is usually practiced frequently depends on the moral virtues, where fear can prevent one from speaking out against unfair or dangerous conditions, and one’s self-interest must be balanced against the interests of other stakeholders, proper aims of the organization, and the engineering profession.

For the secular philosopher-engineer, the final goal of the processes, the individual engineer and the profession, and the employing organizations is social eudaimonia.

In addition to being a virtue, techne is also important in Aristotle’s study of material beings (Aristotle 1999). It refers to the principle of beings whose formal, efficient, and final causes depend at least in part on an external agent. It is described in contrast to the principle of physis (nature), for which these causes are inherent to the being. A natural being such as an acorn does not depend on an external agent to take its form, in contrast to a wooden bed frame, which, if it were to sprout, would yield a tree—the bed frame comes to be through the crafter. To use another of Aristotle’s examples, a medical doctor whose body automatically heals itself operates according to physis, whereas the doctor prescribing a medicine is an act of techne. The principle of engineered objects is techne. For premoderns, nature offered a normative orientation toward harmony and proportionality, though sometimes human participation made possible a perfection. While Heidegger traced the perniciousness of modern technology back to Aristotle’s techne, Aristotle did not think of it as the way of thinking. He subordinated practical concerns, which were ephemeral, to intellectual virtue, especially contemplation (theoria).

Aristotle offers a few resources that can be used to understand social institutions, which can be applied to the professional societies of engineering. Professional societies often aim to provide the three kinds of friendships that Aristotle differentiated. Social activities of the society aim to provide some pleasure for their members. The connections forged in them regularly offer mutual professional benefit. Societies seem to flourish, though, when their members have a friendship of the highest kind, which arises between virtuous individuals and that inspires further development of intellectual and moral virtue. This form of friendship results in camaraderie between members; its emphasis on virtue and social eudaimonia also directs these societies toward the common good. The orientation toward the common good is especially important for engineers, whose work affects all people, and most engineering societies explicitly mention human welfare or well-being in their codes of ethics.

Aristotelian systems offer a robust framework for thinking about engineering. They have philosophical breadth, give ethical concerns an expansive scope that includes intellectual development and
judgment, and take contingencies found in a world that is continually remade, in part by engineer-
ing, seriously. Yet they can be criticized for, among other weaknesses, (a) being overly relative, so,
e.g., the virtue of courage does little to guide action because it differs among individuals; (b) placing
too much burden on the agent’s judgment, who must determine the beautiful act in each situation
without recourse to rules or methods; and (c) retaining residual elements based on a pre-modern
view of the world separated by two thousand years from the origins of modern engineering, ranging
from remnants of geocentrism to his flawed understanding of the capabilities of women. These issues
are addressed, at least to some degree, by more recent philosophers.

3.2. Immanuel Kant’s Philosophy and Duty Ethics

Immanuel Kant’s focus on necessary and transcendental truths and the limits of reason may appear to
make him weakly relevant to engineering practice, which, as outlined in the previous section, deals
with material and contingent beings and acts. To be sure, his approach and goals are radically different
from those of Aristotelian philosophy, where ethics included the task of sketching, as best as possible
but necessarily imperfectly, the elements of human life, including the moral and intellectual practices
that one can develop over the course of time, that lead to flourishing. Kant (1724–1804), commonly
considered the greatest of the modern philosophers, aimed to purify epistemology and metaphysics
of their errors, whether they be excessive dogmatic affirmations or overly skeptical denials, by con-
sidering the power or faculty of reason itself, namely, an awareness of its operation, the conditions
thereof, and its limitations (Kant 1996). Correspondingly, in ethics, Kant sought to respond to David
Hume’s claim that reason does—and should—serve as a slave of the passions, i.e., reason has merely
an operational and justificatory role in human action (Hume 2007, II.III.3). For Kant, the role of
reason in ethics is to determine the universal moral law that reason can discover and to defend the
prominence of reason over instinct, emotion, and self-interest (Kant 1993).

Kant’s work in metaphysics and epistemology was also provoked by Hume’s recognition that
cause-and-effect can never be experienced: lacking innate knowledge, all that one can say about
previous events is that they happened in a certain way, perhaps according to a certain pattern, in the
past, but there is no way to show that the laws of nature had to be followed in the past or could be
said to be universalizable (Hume 1993 [original 1748], §V Pt I and §VII, Pt II). Hume identified
what is called the problem of induction—one can draw either demonstrative conclusions, which
cannot extend beyond experiences and what is already known, or probable conclusions, which are
provisional. If this problem is real, then the natural sciences, including Newtonian physics, on which
much of engineering rests, stand on unsteady ground. Kant argued that the problem is resolved by
recognizing the existence of another kind of judgments, which he called synthetic a priori judgments,
in which the conclusion extends beyond what is already known and what has been experienced.
These judgments, which make it possible for mathematical and scientific knowledge to be universal-
ized, can be recognized by reflecting on the necessary conditions for all knowledge.

Kant’s systematic explanation provides a grounding for the mathematical, natural, and engineer-
ing sciences that distinguish engineering from related acts of craft or problem-solving. It provides a
justification for universalizing the results of experimental science. Moreover, his designation of space
and time as a priori forms of human perception aligns with the Euclidean spatial grid and undergirds
Newtonian physics, which are still fundamental for engineering practice in many disciplines. In fact,
statics, the study of loads or forces on an object, is the engineering course that nearly all majors have
in common. The emphasis on causality, three-dimensional space, and temporal transformations in
engineering education and practice today largely correspond with a Kantian view of the world.

The emphasis on the unifying and organizing cognitive faculty of reason also powers Kant’s ethi-
cal work. Kant is somewhat dismissive of what can be gleaned from empirical studies of free human
action, aiming instead for a universal moral law, that, by definition, does not depend on circumstances, contingencies, or uncontrollable consequences of one’s action (Kant 2002). Accordingly, the only thing that Kant thinks can be considered good without qualification is a good will, without which no action has moral worth and for which a trade for any other good is mistaken. The will is good when it is aligned with duty. Two intermediaries are necessary for this move from the subjective will to universal duty. First, the will, which is subjective, must express itself in a maxim, a first-person principle of action, such as “I shall make a promise without intending to keep it.” This maxim is then tested against the categorical imperative to determine whether the maxim has been crafted by an impure will. The maxim, and so the will, can be seen to be flawed in two ways. One, when it suffers from an internal contradiction, called a violation of strict or perfect duty, which occurs in the example listed earlier, as the concept of promising requires the intent to fulfill the promise. Two, absent internal contradiction, when it cannot be instilled as part of human nature without the will contradicting itself, a violation of what Kant called broad or imperfect duty. For example, Kant offers the cultivation of one’s talents: no rational being could wish that his or her faculties remain undeveloped or atrophy.

Kant offers three formulations of the categorical imperative, which are different expressions of one law that applies to all humans on account of their rational natures. The first is universalization, wherein one may act only according to a maxim that can be made a universal law. Kant thought people are tempted to carve out exceptions for themselves, such as making a promise to repay borrowed money without intending to keep the promise. The first formulation shows that this is inconsistent—a promissory note depends on the intent to fulfill the promise—and thus immoral. The second is the humanity formula, whereby a human can never be used as a mere means. The third is the formula of autonomy, whereby one acts according to maxims that could legislate universal law for the community, or, expressed from a slightly different perspective, as the formula of the kingdom of ends, i.e., the recognition that one is united with other rational beings—each of which deserves dignity, an intrinsic value that surpasses his or her instrumental value—through shared and related goals, and that each person must be both sovereign and subject of the universal moral law that reason reveals.

Despite the fact that Kant’s moral reasoning ignores contingencies important in ethics—expressly separated from technical rules of skill and counsels of prudence that yield welfare (Kant 1993: Ak. 416–417)—its rational basis and cosmopolitan characteristics have made it important in ethical considerations of engineering and technology. The principle of universalization grounds the ideal of equality, impartiality, and honesty emphasized in many engineering codes of ethics; it also explains why conflicts of interest, situations in which personal interest could reasonably be understood to affect professional decisions, are problematic. The humanity formula provides a grounding for what is called “respect for persons,” concern for each individual based on the person’s dignity, over and above any instrumental value the person has, which at times can run contrary to societal welfare. While engineering risk is often calculated as the sum of the products of the probability of an event and its consequences, the humanity formula adds another perspective on what makes risk acceptable, which depends on voluntary acceptance, informed consent, and, if appropriate, negotiated compensation. Extending the idea behind the third formulation supports the inclusion of more non-experts in technology assessments and public involvement in engineering projects that will affect them. Lastly, Kant’s emphasis on the interaction between the will and reason results in a far simpler moral analysis than one that demands assessing whether an act led to an outcome that was at least as good as any other possible one, which is difficult (or even impossible) to determine, much less to have achieved, in many complex situations encountered in engineering projects.

While Kant’s version of duty ethics is the most popular, it is not the only one. Whereas Kant’s version derives a limited set of universal moral rules based on the nature of the power of reason, W.D. Ross (2002) understands ethics to be a task of identifying the moral principles that undergird thoughtful moral beliefs, which themselves have been tested over time, and through reflection. His
approach, often called intuitionist, yields six \textit{prima facie} \textit{duties}, i.e., duties that may have moral salience in a particular situation. They are duties to:

- fidelity, to keep promises that one has made, and reparation, to make amends for acts that have caused harm;
- gratitude, based on what others have done for the agent;
- justice, the distribution of happiness based on desert;
- beneficence, to do what is possible to improve the lot of others;
- self-improvement, especially in terms of knowledge and virtue; and
- non-maleficence, i.e., not to cause harm.

Unlike Kantian duties, which are absolute and universal,\textsuperscript{6} Ross's duties may or may not hold in a particular situation: it is the responsibility of the moral agent to adjudicate which duties are relevant in a particular situation and to determine the proper course of action, keeping in mind that \textit{prima facie} duties may be in conflict and it might not be possible for an agent to perfectly satisfy all relevant duties. In some cases, imperfect satisfaction of such duties may lead to a moral remainder, i.e., a moral obligation that the agent may need to or try to satisfy in the future.

These duties connect closely with the ethical principles widely adopted by engineers and enshrined into their societal and professional codes of ethics (see Chapter 43, “Professional Codes of Ethics” by Michael Davis, this volume). To give but a few examples, the United States National Society of Professional Engineers Code of Ethics requires engineers to “hold paramount the health, safety, and welfare of the public,” which aligns with non-maleficence, the duty to which Ross gives priority, and secondarily, to beneficence; the duty of fidelity aligns with requirements to be “objective and truthful” in public statements and to avoid deceptive acts. ABET, a U.S.-based accreditor of engineering programs, and the European Network for Accreditation of Engineering Education (ENAE) both emphasize the importance of lifelong learning, which aligns closely with self-improvement. The duty of gratitude offers a justification for commitment to one's profession, which has developed the public reputation, educational system, and tools that new engineers inherit.

While Ross's approach has been criticized for its unsystematic nature, a lack of a central principle, and its docility toward commonly accepted moral belief, its flexibility and responsiveness to varying material conditions and cultural influences make it, at least at first glance, a reasonable ground for assessing engineering activities and professionalism. Moreover, there are parallels between the Rossian moral agent, who must assess the relevant moral features of a situation and determine a good way forward, and an engineer, who is accustomed to assessing the relevant technical considerations for a particular project and determining which trade-offs to make.

Ross's duty ethics blends a weaker concept of duty developed by Kant with concern about the amount of virtue, knowledge, and pleasure (and their fair distribution, justice) in the world. It stands as a midway point between duty ethics and consequentialist concerns.

\section*{3.3. Consequentialism and Pragmatism}

Consequentialism refers to a related set of moral theories that all hold that the moral assessment of an act should be based solely on its consequences, not on motives of the actor or any intrinsic features of the act.\textsuperscript{7} Consequentialists believe that an act is morally right if and only if there is no other act that would bring about better consequences. Generally, the consequences taken into account include those experienced by anyone directly or indirectly affected by the act at the present and in the future.

According to all consequentialist theories, positive consequences are to be sought, and negative consequences avoided. How consequences are understood, however, varies among theories. Hedonistic
consequentialists aim to maximize pleasure and minimize pain; preference-fulfillment consequentialists, as the name suggests, understand an act to be morally right if no other act would result in a better overall state of individual preferences satisfied and fewer left unsatisfied; objective-list consequentialists believe there is a set, common to all individuals, of positive consequences that should be sought and negative consequences that should be avoided. Some consequentialists believe that an act is right if it is expected to bring about the best possible consequences; others believe the assessment should be based on actual consequences brought about. Some believe that the assessment of consequences should be done based on what is expected for each specific act; others believe that the rightness of an act depends on whether it adheres to a set of moral rules that, if widely adopted, would lead to the best overall consequences for everyone.

In most consequentialist theories, the assessment is agent-neutral, i.e., no special concern or priority is given to the agent or his or her close relations. These theories are usually considered utilitarian. Among the others, ethical egoists consider only the consequences experienced by the agent, and some varieties give preferential treatment to the consequences experienced by the agent and those close to him or her.

Consequentialist principles attempt to neutralize the force of custom or dogmatic beliefs in determining right and wrong. Utilitarian principles work against exaggerated self-concern and encourage consideration of the broader impacts of what one does; they have often been cited by social reformers as a justification for considering the welfare of groups lacking political or economic power. Out of the various ethical theories discussed in this chapter, utilitarianism is perhaps easiest to extend to animal ethics, especially in its hedonist form, for it is clear that many animals experience pleasure and pain, and to environmental concerns more broadly, even if only for anthropocentric reasons.

A focus on bringing about the most positive consequences and fewest negative consequences can lead to acts being determined to be right even when positive impacts are small and spread widely and negative effects are experienced by a select group or individual. The need to consider the short- and long-term consequences experienced by all of those affected by the set of possible acts puts a significant, if not impossible, cognitive burden on an agent who is trying to identify the right act, a problem diminished but not solved by applying consequentialist analysis to assess an act after the fact.

A great deal of reasoning in engineering projects and about technological development in general aligns with consequentialist reasoning. The gap between expected outcomes and what actually comes to pass in the adoption of technological innovations mirrors the problem faced by consequentialists. At a societal level, technological adoption is often justified by the promised improvement to overall welfare, even though such innovation may harm certain individuals, especially in the short term. The determination of government regulations for technologies often includes an analysis of utility, especially in the form of a cost-benefit analysis, that takes into account the interests of everyone in society. Cost-benefit analysis has parallels with utilitarian reasoning, although consequentialists do not reduce happiness strictly to economic terms. Cost-benefit analysis is frequently used by corporations to determine which option to pursue based on an assessment of the overall consequences to the company (Hansson 2007), which, considering the corporation as a person and excluding external impacts, is an egoistic approach. Cost-benefit analysis and utility calculations have been connected to engineering since their origins around the 1840s: the practicing French engineer Jules Dupuit is considered the founder of the cost-benefit approach and has been called “the progenitor of public economics, welfare economics, demand analysis, price discrimination, the compensation principle and the theory of economic surplus” (Maneschi 1996: 411). Risk analysis, especially in probabilistic risk assessment, often uses a utilitarian form of reasoning to consider overall outcomes with little or no consideration given to what will happen to a select group of unfortunate individuals and without concern over who those individuals might be, which can result in issues of justice, especially environmental justice (see, e.g., Shrader-Frechette 2002).
More generally, Thomas Tredgold’s (1828) early definition of engineering as “the art of directing the great sources of power in nature for the use and convenience of man” has largely been accepted through to the present. The term “use and convenience” is also found under the heading of utility in the writing of Hume, who accepts it as an unproblematic principle for morals (Mitcham and Briggle 2012). Tredgold’s definition concludes with a listing of infrastructure improvements for transportation, production, and commerce, aims that align closely with civil and mechanical engineering today. According to a definition from British engineer G.F.C. Rogers, adopted and modified slightly by Walter Vincenti, engineering is “the practice of organizing the design and construction [and operation] of any artefact which transforms the world around us to meet some recognized need” (Vincenti 1990: 6).

This definition encompasses the labor of more disciplines of engineering and also includes consumer goods; the focus on “recognized needs” could be understood in consequentialist terms as a satisfaction of desire, an element from an objective list, or pleasure. To the degree that engineering focuses on efficiency as the consequence to be sought and inefficiency an evil to be avoided, it also aligns with consequentialist reasoning. Moreover, Hume’s attempt to apply the scientific method to a study of human nature aligns with the scientific approach that engineers apply to technoscientific problems.

The idea of utility is also central in pragmatism. In Pragmatism, a book dedicated to John Stuart Mill, William James defined the pragmatic method as “the attitude of looking away from first things, principles, ‘categories,’ supposed necessities; and of looking towards last things, fruits, consequences, facts” (James 1965: 47). Whereas consequentialist theories focus almost exclusively on ethics, pragmatism gives greater emphasis to epistemic concerns, but not for their own sake. Whereas previous epistemologies emphasized correspondence between one’s understanding and what existed, and coherence between the objects of one’s understanding, pragmatists added another criterion, namely the usefulness of what one knows. James said, “any idea that will carry us prosperously from any one part of our experience to any other part, linking things satisfactorily, working securely, saving labor; is true for just so much, true in so far forth, true instrumentally” (James 1965: 49, italics in original). Importantly, these truths prioritize an experiential account of knowledge, with priority given to scientific knowledge. This account marries the trial-by-error origins of engineering, an approach which still is the foundation of engineering and manifests itself through the evolutionary development of our technology and the engineering practices that create it, with its emphasis on natural and engineering sciences; it shares the orientation toward usefulness and instrumentality found from Tredgold forward; moreover, a pragmatist’s acquisition of knowledge is experiential and active, not primarily observational and receptive, i.e., it is a process of learning, not mere description of what is observed.

Similarly, compare fellow pragmatist John Dewey’s process of inquiry to the engineering process. Dewey defines inquiry as “the controlled or direct transformation of an indeterminate situation into one that is so determinate in its constituent distinctions and relations as to convert the elements of the original situation into a unified whole” (Dewey 1982: 319–320, italics removed). Inquiry, which holds for the bodily, cultural, and natural realms as well as the mental realms, progresses through five stages. First, one recognizes something problematic (unease, uncertainty, incoherence, etc.) in the current state of one of the realms or between realms. Second, one needs to conceive and express the problem. Third, based on observable facts, relevant solutions are proposed, which is analogous to forming a scientific hypothesis. Fourth, one considers how well the possible proposed solutions work in the four realms, often iteratively moving the reasoner closer to the most relevant solution, which is analogous to experimental tests of a scientific hypothesis. Fifth, the solution is operationalized, i.e., this new state of affairs is tested against other observed facts, especially those that come to light as the agent acts (Dewey 1982: 320–329). This process parallels the engineering design process, where the steps would be gap analysis or opportunity identification; requirements definition; design; modeling and testing; and project execution. Billy Vaughn Koen (2003: 28) describes the engineering method in terms almost identical to Deweyan inquiry: “the engineering method (often called design) is the use of heuristics to cause the best change in an uncertain situation within the available resources.” Heuristics, often called rules of thumb, are plausible and useful (but not necessarily true) aids that

Perhaps the closest connection between pragmatism and engineering comes by way of technology. Dewey came to see all inquiry as technology. In Larry Hickman’s words, for Dewey “every reflective experience is instrumental to further production of meanings, that is, it is technological” (Hickman 1990: 40–41, italics in original). Mario Bunge (1967) similarly used a broad definition of technology, which includes material, social, conceptual, and systems realms, combined with logical positivism, to develop the pragmatism–technology–engineering connection. Bunge’s attempt to find a technoscientific ground for philosophy has been called “perhaps the most comprehensive vision of engineering philosophy of technology” (Mitcham 1994: 38). Economist Herbert Simon uses utility and statistical decision theory, combined with heuristics, computational methods, and context appropriateness, to develop an engineering design methodology that includes engineering, operations, and management, one that can even explain most complex human behaviors as “the search for good designs” (Simon 1996: 138). More recently and from a Chinese perspective, Wang Dazhou has used Dewey to develop an experimental philosophy of engineering that recognizes the importance of human experimentation in shaping and responding to “the co-evolution of humans, artifacts, and engineering practices” (2018: 49).

3.4. Conclusion

Philosophy of engineering is still embryonic, and few investigations into engineering explicitly situate themselves in a philosophical tradition. Analyses of practices, methods, and artifacts often ignore their historico-philosophical context, and they often implicitly adopt pragmatism, the tradition most compatible with an engineering way of thinking. On the one hand, these common approaches avoid errors of dogmatism and the risk of importing obsolete ideas by focusing on the ethical and epistemic processes themselves. On the other hand, they ignore many resources from other philosophical traditions that have been developed as craft knowledge has evolved into contemporary engineering. These resources can be useful in thinking through engineering practice and its social institutions, and they counteract tendencies to think about engineering as a quasi-sufficient way of life, one in which in which the world and the people in it are merely problems to be solved or resources that need to be optimized.

The three traditions investigated in this chapter provide a reasonable composite view of the relationship between philosophical theory and engineering, but one that is of course nowhere near complete. It ignores feminist approaches to engineering (see Chapter 48, “Feminist Engineering and Gender” by Donna Riley, this volume) and Eastern philosophy (see Chapter 4, “Eastern Philosophical Approaches and Engineering” by Glen Miller et al., this volume), and it offers just a cursory mention of religiously influenced philosophies. These other intellectual resources can contribute to a more comprehensive and insightful understanding of engineering, especially in their critiques of engineering practice, its social institutions, and its way of thinking, and in their imaginative potential to address the problems, excesses, and deficiencies in engineering and the technology it produces. Furthermore, recontextualizing engineering and various philosophical traditions offers the advantage of stimulating the development of these traditions through serious consideration of engineering practice, its social organizations, and the sociotechnical systems that it produces and that surround us in what has been called the Anthropocene.

Related Chapters

Chapter 1: What Is Engineering? (Carl Mitcham)
Chapter 4: Eastern Philosophical Approaches to Engineering (Glen Miller, Xiaowei (Tom) Wang, Satya Sundar Sethy, Fujiki Atsushi)
Chapter 5: What Is Engineering Science? (Sven Ove Hansson)
Chapter 6: Scientific Methodology in the Engineering Sciences (Mieke Boon)
Chapter 48: Feminist Engineering and Gender (Donna Riley)
Chapter 53: Engineering and Contemporary Continental Philosophy of Technology (Diane P. Michelfelder)
Chapter 54: Engineering Practice From the Perspective of Methodical Constructivism and Culturalism (Michael Funk and Albrecht Fritzsche)

Further Reading

Notes
1. G.E.M. (Elizabeth) Anscombe and Etienne Gilson were two of the most prominent virtue ethicists during the early renewal; more recently, Alasdair MacIntyre, Rosalind Hursthouse, and Philippa Foot have been influential in developing the tradition.
2. In Thomistic thought, the political is subordinated to the supernatural, most importantly knowing God and acting according to his will, i.e., being related to Him, and other created beings, in charity or love.
3. The translations of the moral virtues are more adequate; the Greek for courage is andreia, temperance sophrosune, and justice dikaiosune.
4. For an extended discussion on techne and episteme, see Mitcham (1994: 119–125) and Mitcham and Schatzberg (2009).
5. The relationship between episteme and nous, described at length in Aydede (1998), is less clear than that between episteme and techne. For the purpose of this chapter, I treat nous as primarily grasping foundational truths without considering how that happens.
6. Self-improvement and beneficence (and non-maleficence) are imperfect Kantian duties, which are always in force but must not always be fulfilled.
7. Jeremy Bentham, John Stuart Mill, and Henry Sidgwick are the most important early utilitarians; more recent expositors include R. M. Hare, Derek Parfit, and Peter Singer.
8. I have developed this point to at some length in “What Ethics Owes Engineering” (Miller 2018).

References


