CONTINGENCY IN ENGINEERING PROBLEM SOLVING UNDERSTANDING ITS ROLE AND IMPLICATIONS: FOCUSING ON THE SPORTS MACHINE

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Manuscrito recibido: 08/05/2023
Manuscrito aceptado: 22/05/2023

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Abstract

Engineering problem-solving plays a critical role in addressing complex challenges and advancing technological advancements. However, the effectiveness of problem-solving approaches can be influenced by various contingencies that arise during the problem-solving process. This study aims to explore the role of contingency in engineering problem solving and its implications for successful outcomes. The research employs a mixed-methods approach, including qualitative interviews with engineering professionals and quantitative analysis of problem-solving performance data. Through in-depth interviews, the study explores the experiences and perspectives of engineers when faced with contingencies and how they navigate through them. Quantitative analysis of problem-solving performance data provides insights into the effectiveness of different adaptive strategies in achieving successful outcomes. The findings of this research contribute to a deeper understanding of the dynamic nature of engineering problem solving and the adaptive capabilities required to address contingencies effectively. The implications of the study inform engineering practice by highlighting the importance of flexibility, resilience, and strategic decision-making in the face of contingencies. By identifying and analyzing the contingencies encountered in engineering problem solving, this research provides valuable insights to enhance engineering education and training programs. The study's findings can inform curriculum development, professional development initiatives, and decision-making frameworks, ultimately improving the problem-solving skills and outcomes of future engineers. Overall, this research advances our understanding of the role of contingency in engineering problem-solving, providing valuable insights into the adaptive strategies employed by engineers and their implications for successful outcomes. By addressing the challenges posed by contingencies, engineering professionals can better navigate complex problem-solving situations and drive innovation in the field. Please note that this is a general example, and you can modify and adapt it to align with the specific focus, methodology, and findings of your research.

Keywords: Problem-solving. Contingency in engineering. Engineering. Psychology

Introduction

Intellectuals, and especially philosophers, have looked down on engineering for reasons that go back to the very foundations of Western culture in ancient Greece.1 The causes are indicative of long-standing biases that have persisted for over 2000 years (Alyaseri et al, 2023; Alyaseri et al, 2022). The low value that intellectuals have historically placed on the contingent, the probable, the particular, the contextual, and the temporal is particularly relevant to the ongoing underestimate of engineering. But philosophers, in particular, have always placed a premium on what is indispensable, certain, universal, independent of context, and timeless. By placing theory, value-neutral principles, and deductive reasoning at the top of the hierarchy, we leave ourselves ill-equipped to cope sensibly with real-world situations including practise, values, emotion, and volition. In fact, when viewed through the lens of necessity, life and behaviour are inherently illogical. In the Western 'high' culture of ideas, education, art, morality (and the monotheistic religions (Alyaseri. 2021; Salman et al, 2022), engineering serves as an archetypal example of what is undervalued. Engineering is highly specific, subject to imposed value judgements, and a matter of chance. Its approaches to solving problems are situational, multifaceted, open to uncertainty, adaptable, and action-oriented. In contrast, mathematics is emblematic of what has been most appreciated in Western 'high' culture, especially reasoning that is abstract, necessary, and value free; and problem solutions that are universal, certain, unique, and ageless (Almagsoosi et al, 2022). Rejecting reasoning based on the probable, the concrete, and the contingent, the most eminent Western philosophers from Plato and Aristotle to the early Wittgenstein have aspired to the style of reasoning known as "demonstration," which refers to mathematically deductive argument. From Descartes and Galileo to Einstein and Schrödinger, modern science has been clothed in a tradition of reasoning "in the geometric manner (Ashham et al, 2017)." By the 20th century, the general public had come to recognise science as the gold standard for applying reason to experience and, by extension, as the only discipline with the potential to reveal the unvarnished truth about the world. Science's use of esoteric mathematics and a hybrid experimental logic that seems deductive (but is actually an instance of the 'fallacy of affirming the antecedent', as identified in the seventeenth century) contributes to its widespread acceptance (Raheemah et al, 2021; Subhi et al, 2022). As a result of conflating knowledge and truth with necessity and related notions, we have severed the ties that bind reason and action, as seen by the fact that scientists are given more respect than engineers. The ancient thinkers had already accepted this divorce as a truth, and it continued to have a significant impact throughout the twentieth century. Aristotle maintained that there can be no "science" of action because of the inherent uncertainty, specificity, and contingency of human activity.2 What is meant by 'knowledge' and'science' is the necessary, the universal, and the certain, therefore they cannot govern action. This makes it so that deductive thinking, while important and capable of achieving certainty, cannot cross the gap between theory and practise. So, by definition, behaviour is a product of one's own volition and is driven by fundamentally irrational desires(Sharaf et al, 2022; Mouhmmd et al, 2023).

Several cultural critics panned this view of rationality in the nineteenth century, and several major philosophers investigated alternative, contingent conceptions of rationality in the twentieth. With some notable exceptions, such as John Dewey, these theorists did not take the modern technical spectacle as evidence that an efficient contingency-based model of rational action was being manifested in engineering. However, the advent of ground-breaking new scientific ideas and advancements in mathematics and logic only served to bolster the preconceived notion that the kind of necessity-based rationality embodied by science was the essential key to unlocking the secrets of the universe. As time went on, engineering solidified its role as science's auxiliary.

The Relationship between Engineering and Other Aspect of Life

The scientific community often refers to engineering as an applied science, and this description is widely accepted, not only by the general public but also

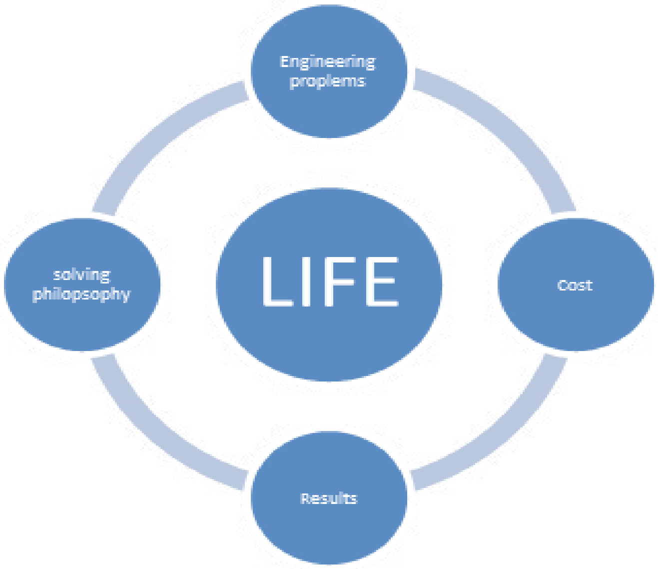

Figure 1: The cycle of engineering vs Life.

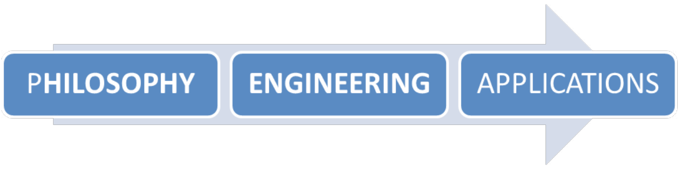

Figure 2: Basic elements of engineering.

by the engineering community and its leaders. This definition of engineering was incorporated into Science: The Endless Frontier, a report to the President submitted in 1945 that would go on to have a profound impact on postwar American science and technology policy.3 Vannevar Bush, a former MIT electrical engineering professor and president of the Carnegie Institution who was appointed by President Franklin D. Roosevelt in 1940 to head the Office of Scientific Research and Development (OSRD), authored the study. Due to OSRD's tremendous performance during the war, Bush was able to argue for a change in the long-standing US policy of not allocating public monies to assist "pure" science.

Bush was fully aware that many of the achievements hailed as scientific by OSRD were actually technical feats. This included the atomic bomb, radar and electronic countermeasure devices, mass production of penicillin and blood plasma, and the pioneer electronic computer ENIAC. Politically adept, he also understood the higher cultural value placed on scientific knowledge. In addition, employing public monies to promote engineering related activities ran counter to the idea of industrial capitalism because, by 1945, engineering was mainly absorbed into profit driven firms. Therefore, Science: The Endless Frontier posited a scenario in which public funding for "pure" scientific research was essential because only such objective study of the natural world could produce the kind of knowledge that, once disseminated to engineering and industry, could spark economic growth and serve as a foundation for future national security.

Proprietary industrial research laboratories on one hand and, in Germany, publicly funded research institutes on the other were motivated by innovations in the chemical, electrical, transportation, and communication industries, which were systematically coupling science and engineering. Commercially successful innovations prompted new science, which enabled new engineering, which led to improved or new applications, which in turn fueled further research and newer innovations; this cycle repeated itself in almost every instance of innovation, from the steam engine and the telegraph to the photocopier and the computer. Since the 1960s, STS (science, technology, and society) courses have helped educate a generation of young people about the social, political, and ethical implications of technology.5 However, with the exception of engineering ethics classes, practically every subject in these curricula treats engineering as if it were a black box, a stage in the technological innovation process, or, in case studies, technical problem resolution. Few discussions revolve around engineering in its typical industrial or governmental setting. However, STS research has produced a far more nuanced appreciation for how technical advancement is a multifaceted social process. This method involves the strategic application of technical expertise to advance institutional goals motivated by economic and/or political considerations.6 Engineers play a crucial role in facilitating the selective utilization of technical information, and understanding how they do so is essential to appreciating engineering as an exemplar of a unique kind of rationality in contrast to science. Whatever the causes of engineering's poor cultural status, society as a whole suffers.7 Ever since the early stages of the industrial revolution in the late eighteenth century, technological advancement has been one of the most influential forces in shaping society. Throughout the 20th century, technology's capabilities grew at an exponential rate, posing severe social, political, and environmental issues. Our remedies to these problems have been pathetically inadequate because we've been too busy debating the relative merits of different universal moral, ethical, political, and philosophical concepts. Technology policy debates become mired in ideological disagreement because, after 2400 years, there is still no agreement in mainstream Western philosophy on what these universal and indispensable social, ethical, and political values are.

The application philosophy in engineering problems

Both the nature of engineering problems and the kinds of solutions that are deemed acceptable are highly contextual and therefore independent of the engineers' technical knowledge. The anticipated economic, social, and/or political repercussions of implementing solutions to engineering challenges are the source of these value assessments. This evaluation of repercussions is a reflection of the reality that engineering is always done in the context of particular commercial and/or political action. Therefore, engineers need a superior or client to do their duties.9 However, scientists are seen as disinterested people who only want to find out the truth about everything. Nature, not their bosses, poses the challenges they must overcome, and Nature alone decides which strategies are best.

Engineers typically work for companies whose upper management has already decided on a course of action and hired them to implement it. While research may be motivated and funded by an action agenda, such as in the case of nuclear science in the Manhattan Project, value judgments that are external to the methodology of science are not permitted to play a role in defining problems or proposing solutions. Engineers, of course, rely on mathematical and scientific knowledge in order to solve their problems, but they do so in ways that are completely foreign to the methods used by mathematicians and scientists. When solving engineering challenges, engineers apply mathematical and scientific knowledge in ways that are similar to how scientists apply mathematics and technology when solving scientific problems. For physicists, mathematics provides a source of conceptual 'tools' to be employed opportunistically in order to solve physics issues to their satisfaction. It doesn't matter to physicists if mathematicians are upset that "their" mathematics is being utilized in this way or if they don't accept as mathematical answers the solutions accepted by physicists for physics problems.

The same holds true for the application of mathematical and scientific principles by engineers. These are conceptual tools and approaches that engineers can utilise flexibly and according to their own standards. Furthermore, when engineers use scientific and mathematical materials, they must modify the universal nature of these materials to fit the specificity of engineering problems. Thus, engineering is merely an applied science in the same way that physics is merely an applied mathematical discipline. When considering engineering as an applied science, it is important to note the significant distinction between engineering design and scientific theorising. Even while there may be competing scientific explanations for a given phenomena at any given time, there is ultimately only one "true" explanation that accurately describes reality. However, due to the importance of contextual value judgments-which, from the perspective of practicing engineers, can look arbitrary-design is an irreducibly pluralistic exercise of reason. Engineering problems and the parameters within which they will be recognized as acceptable solutions are defined in terms of these contingent value judgments, which are embodied in performance specifications and specification of size, weight, production cost, reliability, materials, time to market, manufacturability, and serviceability. Moreover, designs are malleable; they change over time as the relative importance of problem and solution parameters shifts.

Therefore, design is not only highly specific, but also a process that is rooted in the past. However, true scientific theories do not change; they should be static in nature. In contrast to the pursuit of truth by scientists in engineering design, "bounded rationality" and "satisficing," terms coined by Herbert Simon to describe managerial decision-making, are at work. These terms refer to the conscious decision to work with limited information and to implement solutions deemed adequate rather than optimal.10.

Science is value neutral and its objective understands, but engineering challenges are expressly action focused and driven by value judgments. The 'revolution' in scientific methodology that began in the 17th century was based on a central tenet: the separation of knowledge from its topic. As a result, this broke the link between such information and the subject's subsequent behavior. When it comes to taking decisive action, scientific evidence is mixed.

That is, the question of what we should do with our newly acquired scientific knowledge cannot be addressed by science. However, technology is inherently goal-oriented. Just as cars are for getting from point A to point B, so too is a theory of the nucleus a theory of the nucleus, and not 'for' producing a bomb or a nuclear reactor, or any other purpose other than absorption into a larger theory.

Putting scientific findings into practice necessitates the addition of non-scientific value judgments, such as those made by governments and business owners. Francis Bacon and René Descartes, the fathers of modern science, claimed that scientific knowledge would give us control over nature so that we could better the human condition through our discoveries. However, by the end of the seventeenth century, it had become clear that gaining scientific knowledge and bettering the human condition were two separate and unrelated endeavors.

The Effect of Engineering on the Other Sciences

Just as the rationality of necessity-based philosophy is distinct from the rationality of contingency-based philosophy, so too may the rationality of engineering be regarded as separate from the rationality of science. The fact/value distinction is central to so-called 'hard' scientific reasoning but impossible for engineering reasoning; and engineering problem solving inherently anticipates action, whereas scientific problem solving does not; these two differences are particularly important for identifying these as two different conceptions of rationality.

There was, in fact, an open "war" in the development of Western philosophy between two conflicting views of rationality, represented by the contradiction between the PSR and PIR idea clusters. The conflict begins with Plato's Gorgias13, in which the Sophists are portrayed as abusive of reason, as instructors of rhetorical strategies rather than the good, the right, and the true. They are not seekers of wisdom like Socrates, and hence cannot be called philosophers. As historian Nancy Struever puts it, the Sophists consciously rejected Plato's ideal sphere of pure reason and flawless justice as the goal of philosophy in favour of the unpredictable arena of action and speech.14 The Sophists rejected the idea that there could be such a thing as absolute truth or value, as well as the idea that the universal is better than the specific and that abstract theory is better than practical experience.

The Sophisitcs saw the primary function of philosophy as providing insight for practical application. Rhetoric was not just the art of persuasion for them; it was also the process of learning how to behave appropriately in social situations through words. The Sophists believed Plato's pursuit of "purity of thought and communication" to be an illusion, and they viewed the ability of deductive logic to persuade as being "mediated through the passions, not just the intellect" (Struever, once more). Protagoras's argument, ridiculed by Plato15, that 'Man is the measure of all things' indicated a view of philosophy as anchored in experience, rather than in an unexperienced and experienceable'reality' that transcended experience. Understanding how people behave, how Man'measures' things, how individuals individually and collectively assign values to their experiences, is crucial to the quest for determining the optimum way for a person to perform. The Platonic-Aristotelian victory over philosophy elevated activity to understanding but was couched in terms that denigrated an emphasis on action as base. Using the reality that experience is in fact contingent, particular, and uncertain, Isocrates, a contemporary of Socrates and a pupil of Gorgias, argued vehemently but unsuccessfully against this interpretation of philosophy. Isocrates recognized, decades before Aristotle, that the philosophical foundations of inevitability, universality, and certainty required a detachment from experience that rendered such knowledge useless for action. Isocrates used the insulting epithet "sophist" to criticise Plato in the Antidosis. He said that, rather than the rhetoricians, it was Plato who was the sophist for teaching the sort of intellectual gamesmanship that did nothing to aid us in our decision-making. The rhetoricians were the actual philosophers because they sought knowledge that could be put to use. Augustine, once he converted to Christianity, believed it was his duty to refute scepticism since Christianity teaches that there is an ultimate truth. However, during the late mediaeval period, challenges were being raised within Christian institutions regarding the importance of necessity and universality in philosophical and theological argumentation. Both Duns Scotus and William of Ockham, writing in the fourteenth century, emphasised the importance of will and particularity to sound reasoning. The Renaissance revival of Cicero's writings in the fifteenth century, and the translation into Latin of Classical sceptical philosophical manuscripts in the sixteenth century, exacerbated the political as well as the intellectual and theological controversies sparked by this shift from universal to particular and from logic to will.19 The Protestant Reformation, the Catholic Counter-Reformation, and Renaissance philosophy all grappled with fundamental questions about the nature and limits of rationality, including the claims of certitude and probabilism. During the Renaissance, chance began to challenge necessity as the cornerstone of philosophical and rational thought. The Humanists' explicit declaration of cultural 'war' in their resurgence of rhetoric and history as the 'real' foundation of philosophy because of their emphasis on action and embrace of particularity and contingency. "Rhetorical concepts of discourse emphasise change, the many, the particular, and the emphases that are essential in a serious commitment to historical understanding, i.e. historicism."20 Indeed, it was the Humanists who came up with historicism, which incorporates concepts like relativism, open-mindedness, and pluralism. Rhetoric, like engineering, is inextricably linked to doing, to choosing choices that lead to doing, and to drawing distinctions that serve to 'rationalise' those choices. Rhetoric, like engineering, seeks to impose order in a chaotic social world by rational argument. It's no surprise that the beginnings of contemporary engineering may be traced back to the Renaissance.

The Basic Element of The Philosophy of Engineering

The societal backdrop of modern engineering practice is rooted in the rise of industrial capitalism in the middle of the twentieth century. These factors are now dispersed worldwide in ways that are unconcerned with borders, ideologies, or social structures. The procedure that engineers follow is the unifying factor. The preceding discussion refers to the fact that engineering is being used to further managerial goals in this procedure. Engineers use their skills to find answers to issues brought on by various agendas (whether commercial, political, or military), which in turn pave the way for their implementation. Thus, engineering cannot be separated from its social and political contexts. Historically, engineers in the Anglo-American world have claimed that they are only technical problem solvers and that others must bear responsibility for any actions taken in light of their solutions and any resulting consequences. When one considers the inherent limitations of engineering and the cumulative detrimental effects of technological action, however, such conviction rings hollow.

Engineers cannot absolve themselves of responsibility for their work because of the inherent contextual character of technical thinking. Only within the context of an action philosophy, however, can we reasonably apply value judgments to the actions that engineering and engineers make possible. Those who approach technology policymaking and technology assessment from the perspective of the necessity-based intellectual-philosophical tradition will always struggle to arrive at a 'rational' conclusion. For example, they may assume that the process requires identifying universal principles and values from which 'right' technological action and 'good' engineering can be deduced, or that since this effort is fruitless, the process should take as its goal a 'futile' compromise.

John Dewey began methodically developing "pragmatism" in the 1890s, but it was first introduced by Charles Sanders Peirce in the 1860s and '70s and popularized by William James around the turn of the century. To me, pragmatism offers the most promise for a meaningful and workable engineering ethics, as well as for the rational evaluation of technological activity and engineering as its enabler. Dewey's pragmatism relies heavily on the concept of "instrumentalism," and elucidating this term helps to shed light on a number of related ideas. In the necessity based/principle of sufficient reason philosophical tradition, the term "instrumentalism" is derogatory because it suggests an emphasis on means rather than ends, on completing a task rather than investigating what makes the task worthwhile. (Since an agreement has not been reached after 2400 years, philosophers ascribe the highest value to the pursuit itself; this is a tactic Plato used to explain why Socrates was unable to name the universal ideals he upheld. However, what Dewey meant by "instrumentalism" is very different from what the term denotes in conventional philosophical usage. According to Dewey, it is the content of consciousness, the intricate process by which we respond to experience consciously and effectively. In turn, consciousness is the interacting, changing, ultimately intersubjective process of selected interest, active engagement, and ongoing change that generates experience. The concepts of "mind" (the experiencer) and "world" (the experienced) are mental constructions that falsely ascribe "thinghood" to different parts of this process. Consciousness itself is a process, a dynamic process that is real. Our attentional biases and the need to impose order, closure, anticipation, and control on a world and a self that are in constant flux are manifestations of the self-active nature of consciousness. More generally, Dewey's theory centers on the personal nature of the process through which we create interest-based distinctions and choose ascribe thinghood. He used this to argue against dualism, against the idea that there are 'atomic' realities apart from the process that have fixed features, and against any other form of abstraction from experience. Of course, the mind always attaches thinghood to features of the content of experience, but the meanings we assign to concepts like space, time, matter, energy, the atom, the gene, the earth, and the universe change throughout time as new information and new interests come to light.

Inquiry, or thought centred on some aspect of experience that emerges as problematic and prompts a reaction to addressing that problematic, is simultaneously created by the active and interested character of awareness. Dewey's pragmatism centres on explaining the logic of inquiry, and instrumentalism is a reference to that logic. Cognitive awareness manifests as inquiry when one ponders the desirability of altering some aspect of the world in order to get rid of something unpleasant or to introduce something desirable that is now missing.

Conclusion

In contrast to the necessity-based paradigm of rationality that has dominated Western philosophy since Plato and is the foundation of modern science, the engineering approach to problem-solving emphasises the possibility of alternative outcomes. Necessity is a notion that is closely related to others, such as certainty, universality, abstractness, and theory. In contrast, engineers are stubborn, specific, particular, probabilistic, concrete, and practical. Our capacity for effectively applying reason to action has been weakened by our tendency to equate rationality with necessity. This essay argues that a contingency-based philosophy of engineering could facilitate more effective technological action by situating engineering's contingency-based reasoning within a philosophical tradition spanning from pre-Socratic philosophers to American pragmatism.

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