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Bocong Li

An Introduction to the Philosophy of Engineering

I Create, Therefore I Am

Springer

Philosophy of Engineering and Technology

Volume 39

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ISSN 1879-7202 ISSN 1879-7210 (electronic)
Philosophy of Engineering and Technology
ISBN 978-3-662-64087-6 ISBN 978-3-662-64088-3 (eBook)
https://doi.org/10.1007/978-3-662-64088-3

This Springer imprint is published by the registered company Springer-Verlag GmbH,
DE part of Springer Nature.
The registered company address is: Heidelberger Platz 3, 14197 Berlin, Germany

A Philosophical Reflection of the Humanized Natural World: Foreword to the Chinese Edition

Professor Li Bocong 李伯聪 has been devoted to research in the philosophy of engineering for more than 20 years. To my great pleasure, his research has resulted in a new bloom in the philosophical garden. One of the most representatives of his research is *Gongcheng zhexue yinlun: Wo zao wu gu wo zai* 工程哲学引论: 我造物故我在 [*An Introduction to the Philosophy of Engineering: I Create, Therefore I Am*].

Philosophy is often described as nothing more than a theoretical version of the way human beings look at the world, in a disciplinary system composed of many subdisciplines. The objects of philosophical focus have undergone historical changes. In the West, ancient philosophy emphasized ontology, while early modern philosophy was more concerned with epistemology. Since the mid-nineteenth century, further major changes occurred with the development of science and humanism, in conjunction with which Marxist theory has made important contributions to both theory and practice.

Karl Marx famously wrote in his "Theses on Feuerbach": "The philosophers have only interpreted the world, in various ways; the point is to change it." Marxist philosophy is not only to interpret the world but more importantly to transform it, so that Marxist epistemology is grounded on practice that joins subject and object.

In the effort to exploit and change nature for survival and development, humans do everything possible creatively and variously during an artificial, or what is called engineering process. It is in this sense that *An Introduction to the Philosophy of Engineering* can be described as a groundbreaking new work in the modern philosophical system and belongs to what Marx calls the philosophy of transforming the world.

In understanding and changing nature, the connected realms of science, technology, and engineering play distinctive roles. It is from this perspective that this book presents the idea of triism. Modern philosophy has seen varied schools of philosophy of science and of technology, each in its own right, but there have been few monographs literally called "the philosophy of engineering". Thus, this book naturally meets a need in modern social development. It is sincerely hoped that more of its kind should arrive on the scene in Chinese philosophy, so that the three sister

disciplines of philosophy of science, philosophy of technology, and philosophy of engineering can respond to and communicate closely with one another.

The French philosopher René Descartes has a well-known proposition, "I think, therefore I am," in which he demonstrates that "I" is the subject of knowing. Highlighted in the title of this book, the new theme, "I create, therefore I am," stresses that in the engineering process "I" is a creating subject. This subject is a human creator who makes a humanized natural world or human-made nature and who creates a "semi-thing-in-itself" that has natural as well as artificial attributes. It might be quite justified to say that humans live not only in the natural world but more immediately in the humanized natural world.

The British philosopher of science Karl Popper turned from epistemology to ontology after the 1950s, thereon proposing the theory of three worlds, which aroused a heated dispute among philosophers and scientists. As he alleges, the universe developed in a swift evolutionary process, in which what happens can be classified into three worlds: World 1 is physical products, including organisms; World 2 mental (conscious) experience; and World 3 products of human minds (theories) or objective knowledge; they are related to and interact with each other. On the basis of exploring Popper's theory, Li Bocong puts forward his theory of four worlds, which carries forward the former and adds his own insight.

In the book, over 50 categories involved in philosophy of engineering, such as planning, decision-making, purpose, operation, institution, implementation, procedure, management, duty, norm, will, four worlds, value rationality, heaven, land and human unified as one, are proposed and analyzed. They actually form a system of categories in the philosophy of engineering and major nodes of a theoretical network.

A modern comprehensive system of philosophy should encompass ontology, epistemology, methodology, and engineering theory. This book stresses that the philosophy of science needs to make a strategic turnabout to view the philosophy of engineering as a core discipline in order to tilt humankind toward survival and development.

Marx asserted that philosophy is the spiritual quintessence of the time. Hence, I wholeheartedly expect that new philosophical spiritual quintessence will be created by giving full play to Chinese national wisdom with the aim of initiating a new magnificent period of Chinese civilization.

May 2002

Lu Yongxiang 路甬祥
Beijing, China

Dr. Lu Yongxiang 路甬祥 was President of Chinese Academy of Sciences, 1997 to 2011.

Making Engineering into Philosophy: Foreword to the English Edition

Li Bocong 李伯聪 is a leading philosopher of engineering and technology in China and the Chinese philosopher with the longest, most sustained, and deepest engagement with philosophy of engineering and technology in the West. Although some articles have appeared in English, *An Introduction to Philosophy of Engineering: I Create, therefore I Am* is the first book. Any Western scholar interested in engagement with Chinese philosophy of engineering and technology discourse will need to take account of this volume.

I was fortunate to meet Prof. Li Bocong on my first visit to China in 1992, when Stephen Cutcliffe (Lehigh University) and I (then at Pennsylvania State University) were invited by the Chinese Academy of Social Sciences to give a series of talks on the development and scope of Science, Technology, and Society (STS) studies in the USA. The talks took place in Beijing at the Graduate University of Chinese Academy of Sciences (now known as University of Chinese Academy of Sciences) where Li was a member of the humanities and social science faculty.

Subsequent to that initial meeting, where I failed to appreciate the significance of his work—my first trip to China was something of a blur—Li Bocong spent the academic year 1994–1995 as a visiting scholar at Lehigh and Penn State. While in the USA, Li participated in a meeting of the eighth biannual conference of the Society for Philosophy and Technology (SPT), held in 1995 at Hofstra University, there he profiled his thesis regarding the philosophical importance of engineering, which had been published in Chinese two years before. From that point forward, he was a regular participant in SPT conferences and associated meetings of what became the Forum on Philosophy, Engineering, and Technology (fPET). Over the next 25 years, Li's articles began to appear in English, but because of their scattered and occasional character, often compounded by in inadequate translation, the significance of his thought has yet to be broadly recognized. This volume offers an opportunity to remedy the situation.

An Introduction to Philosophy of Engineering incorporates in revised form some material from previous publications (which were themselves adaptations from original Chinese books) and provides the first opportunity for non-Chinese readers to engaged significantly with his work. As chapter one reveals, Li Bocong has a better

grasp of the broad development of philosophy in the West than any Western philosopher of technology is likely to have of related developments in China. Chapters 2 through 4 provide a comprehensive overview of engineering as a modern project-based construction process in terms that are likely to resonate with working engineers themselves. Indeed, his analysis has emerged from extensive dialogue with the Chinese engineering community, including members of the Chinese Academy of Engineering. In general, reflecting the influence of Marxism, academic philosophy in China is more engaged than in the West with non-academic practice.

The distinctive Chinese engagement between academic and non-academic worlds is further illustrated by the fact that no other national academy of engineering has sponsored philosophical reflection to the same extent as the Chinese CAE. (For a good study of the character of this Chinese institution, see the translator's "Origin and Operation of the Chinese Academy of Engineering: An Interaction between Expertise and Politics," *Engineering Studies*, 12:1, pp. 39–57.) In no other country have professional engineering associations sought similar formal engagements with philosophers. The only possible exception is the collaboration between engineers and philosophers initiated after World War II by the Verein Deutscher Ingenieure (Association of German Engineers).

The three central chapters place engineering in a broader framework than what is taught in Euro-American engineering schools or conceptualized in English-speaking engineering. For Li Bocong, engineering in a narrow sense is only one aspect of what has become a comprehensive project of human creativity, now sometimes associated with notion of an Anthropocene—although little of the expanding Anthropocenic literature is only beginning to thematize engineering as such. In Li's analysis, the engineering of the world begins with planning and decision-making (Chap. 2), moves through operating and implementing (Chap. 3), and culminates in using and living (Chap. 4). Li's further analysis of each of these moments in the engineering project is rendered in extensive, interdisciplinary dialogue with studies by Chinese and Western scholars in philosophy, history, economics, sociology, management, and business. Li's work constitutes the best effort to date, East or West, at drafting a comprehensive philosophy of engineering and technology sensitive to the practical lifeworld of the engineering community itself.

The concept of an engineering community inclusive of more than technically educated engineers is one of Li Bocong's distinctive contributions. Like any other community centered on a practice—Li references science for comparison, but we could use medicine, law, or religion equally well—the engineering community has a more or less well-defined professional core that interacts with, influences, and is influenced by many other actors and interests. Unlike other approaches, Li's philosophy of engineering places the figure of the engineer in the foreground of a more expansive sociotechnical phenomenon—and then shifts the focus from figure to ground. As he puts it, engineering is always a project that enrolls not just technical engineers but investors, politicians, economists, workers, and users. His final chapter then goes further, seeking to conceptualize implications of the engineering community for all of humanity.

It was only slowly, following our initial meeting, that I began to appreciate the scope of Li Bocong's work. In 1992, he gave me a copy of his book *Bianque he bianque xuepai yanjiu* 扁鹊和扁鹊学派研究 (Xi'an: Shaanxi Science and Technology Press, 1990), which I subsequently discovered is highly regarded among Western scholars of traditional Chinese medicine. It was later that I learned how he had studied geography and classical Chinese before completing graduate studies in dialectics of nature and philosophy and joined the faculty of the Graduate University of Chinese Academy of Sciences.

Following his visit to Penn State, we have continued to meet during my subsequent visits to China and his participations in international conferences. In many ways, his quiet, persistent, and non-confrontational determination to map out a distinctive interdisciplinary philosophy of engineering can serve as a model for other philosophers.

A final note of commendation to the "Philosophy of Engineering and Technology" series editor and to Springer Nature, its publisher: Given the language and scholarly conventions in which this book was originated, it was particularly challenging to produce a respectable translation respecting the specialized scholarly standards for translating from Chinese. Pieter Vermaas and the publisher have invested extensive resources in this publication to honor the author and his translator and to make *An Introduction to Philosophy of Engineering* a worthy addition to the literature. They deserve the thanks of the philosophy of engineering and technology community.

June 2021

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Translator's Introduction

After completing my doctoral studies in the philosophy of engineering under the supervision of Professor Li Bocong 李伯聪, I was fortunate enough to secure a faculty position at the Graduate University of Chinese Academy of Sciences (now simply University of Chinese Academy of Sciences, UCAS) and continue working with him. To oversee the English translation of this volume is thus a special pleasure.

Li Bocong was the first scholar in China to devote himself systematically and comprehensively to research in the philosophy of engineering. This work began in the 1980s when Li Bocong took up some philosophical issues in engineering practice. The initial results were two studies, "Lun shijian lixing 论实践理性" [On Practical Rationality] and "Lun 'gongchenglun' jiqi zai zhexue zhong de diwei 论'工程论'及其在哲学中的地位" [On Engineering Theory and Its Status in Philosophy], presented at Chinese academic seminars in 1984 and 1985. These were followed in 1988 by the publication of *Rengonglun tigang* 人工论提纲 [*An Outline for the Theory of Human Making*] (Li, 1988). In this book, Li emphasized the importance of viewing human making as the central theme of philosophical research. He further analyzed human making processes into three phases: planning and decision-making, implementation and operation, and using and living. The same year saw the publication (Xia, 1988), with an editorial endorsement in the afterword, of an extract and compilation of the above works in *Zhexue dongtai* 哲学动态 [*Philosophical Trends*], a national philosophy journal sponsored since the 1960s by the Institute of Philosophy of Chinese Academy of Social Sciences. These established the foundations for a subsequent monograph, which is now translated as *An Introduction to Philosophy of Engineering: I Create, Therefore I Am.*

In 1992, Li Bocong presented an English paper "On Engineering Realism" to an international philosophical conference held in Beijing. The following year, he published "Wo zao wu, gu wo zai: jian lun gongcheng shizailun 我造物, 故我在: 简论工程实在论 [I Create, Therefore I Am: On Engineering Realism]" (Li, 1992) in *Ziranbianzhengfa yanjiu* 自然辩证法研究 [*Studies of Dialectics of Nature*], a national journal, since 1980, of Chinese Society for Dialectics of Nature/Philosophy of Nature, Science and Technology. Here, he argued for the need to pursue philosophy of engineering as a new area that would be based on the principle of engineering

realism. While the maxim for Cartesian epistemology in the West has been "I think, therefore I am," his philosophy of engineering would be based on "I create, therefore I am." Three years later, the same journal published Li's "Nuli xiang jingji zhexue he gongcheng zhexue lingyu kaituo: jian lun 21shiji zhexue de zhuanxiang 努力向经济哲学和工程哲学领域开拓: 兼论 21 世纪哲学的转向 [Working Hard to Initiate Philosophy of Engineering and of Economy: On the Turn of Philosophy of the 21st Century]" (Li, 1995), which proposed the philosophy of engineering as a new philosophical turn for the twenty-first century.

Shortly after publication of *Rengonglun tigang* 人工论提纲 [*An Outline for the Theory of Human Making*], Li Bocong tried to expand his philosophy to a more comprehensive monograph. Work unfortunately did not progress smoothly. Unable to solve a number of theoretical problems, he turned instead to issues in the philosophy of economics, intending to combine studies in the philosophy of engineering with the philosophy of economics. It was not until 2002 that he was able to complete *Gongcheng zhexue yin lun: wo zao wu gu wo zai* 工程哲学引论: 我造物故我在 [*AnIntroduction to Philosophy of Engineering: I Create, Therefore I Am*] (Li, 2002).

Four distinctive ideas are highlighted in this book. First, Li argues for a *triism* between science, technology, and engineering that recognizes these as three distinct, though related, human activities. The core activity of science is discovery, of technology invention, and of engineering making. This implies that the philosophies of science, technology, and engineering should be established as three parallel disciplines.

Second, Li argues that philosophy of engineering should pay attention not only to the philosophical issues related to technological elements of engineering practice, but also to non-technological ones such as those associated with nature, economics, science, society, and ethics. The philosophy of engineering should involve a broadly synthetic analysis that integrates multiple factors.

Third, Li proposes dividing engineering activity into three phases: planning and decision-making, implementation and operation, and using and living. Planning and decision-making is prominent early in the initiation of an engineering project but does not end then. Engineering is often identified solely with implementation and operation, which are the most obvious of the three phases. But the using and living with engineering is a widely neglected aspect of engineering.

Finally, Li calls for more attention to be paid to the analysis of a number of categories distinctive to engineering itself, once he has analyzed in this book. The maxim of philosophy of engineering is "I create, therefore I am", and its content and significance are more important than another philosophical maxim "I think, therefore I am".

Independently and parallel to the work of Li Bocong, in the 1980s and 1990s, some Western philosophers also began developing the philosophy of engineering. In 1991, Paul T. Durbin edited *Critical Perspectives on Nonacademic Science and Engineering*, a collection of European and American contributions to this topic. Important chapters in this volume included Billy Vaughn Koen's "The Engineering Method," Carl Mitcham's "Engineering as Productive Activity: Philosophical Remarks," Steven L. Goldman's "The Social Captivity of Engineering," and Taft H.

Broome Jr.'s "Bridging Gaps in Philosophy and Engineering." According to Broome, research and discussion of the relationship between engineering and philosophy can be done in three modes: philosophy and engineering, philosophy in engineering, and philosophy of engineering. The first results from engineer–philosopher collaborations; the second is the work of engineers writing for other engineers; the third grows out of engineers working to communicate with non-engineers, but remains "an embryonic field" (Broome Jr., 1991). In a foreword to the volume as a whole, which appeared as the fourth volume in the series "Research in Technology Studies," series editors Stephen H. Cutcliffe and Steven L. Goldman further described philosophy of engineering as a "virtually nonexistent discipline" (Cutcliffe & Goldman, 1991).

A year earlier, Goldman also published an article on this topic titled "Philosophy, Engineering, and Culture" in another volume *Broad and Narrow Interpretations of Philosophy of Technology* edited by Paul T. Durbin. Here, Goldman argued that "Today, then, philosophy of science is a fully accepted and highly respected branch of philosophy, while philosophy of engineering carries as much professional distinction as philosophy of parapsychology" (Goldman, 1990). According to Goldman, the long-term neglect of the philosophy of engineering stemmed from a persistent cultural prejudice against practical activities in Western philosophy.

Ten years later, with the turn of the century, things began to change. The philosophy of engineering was increasingly recognized as a discipline in both East and West. This can be observed in relation to four key characteristics that sociologists often use to identify an academic discipline.

First, monographs have been published to establish the academic discipline. As already noted, 2002 saw the original Chinese publication of the volume by Li Bocong that is translated here. The next year witnessed the publication of Louis L. Bucciarelli's *Engineering Philosophy* (Bucciarelli, 2003). In 2007, Yin Ruiyu 殷瑞钰, Wang Yingluo 汪应洛, and Li Bocong collaborated on *Gongcheng zhexue* 工程哲学 [*Philosophy of Engineering*] (Yin et al., 2007). In the same year in Europe, Steen H. Christensen, Martin Meganck, and Bernard Delahousse collaborated to publish *Philosophy in Engineering* (Christensen et al., 2007). Since 2010, Pieter Vermaas has been editing the *Philosophy of Engineering and Technology* book series by Springer, which has published more than 30 volumes, many of which focus on engineering, and to which this translation contributes.

Second, academic conferences have been convened. In China, between 2003 and 2017, there were seven nationwide academic annual conferences on philosophy of engineering. In America, in 2006, Taft H. Broome Jr. convened a meeting at MIT to promote the philosophy of engineering; this led the following year to a Workshop on Philosophy and Engineering (WPE-2007) at Delft University of Technology in the Netherlands. After a second WPE-2008 held at the Royal Academy of Engineering in England, WPE morphed into a Forum on Philosophy, Engineering, and Technology (fPET) which has held biannual even-year meetings ever since. The fPET-2012 conference was co-chaired by Li Bocong and hosted by the University of Chinese Academy of Sciences in Beijing. Other closely related sessions have since 2009 been added to the roster of biannual odd-year conferences of the Society for Philosophy and Technology (SPT).

Third, academic societies have been formed. In 2003, Gongcheng yu shehui yanjiu zhongxin 工程与社会研究中心 [the Center for the Research of Engineering and Society] was founded at UCAS, and the following year saw the official establishment of Zhongguo ziranbianzhengfa yanjiu hui gongcheng zhexue zhuanye weiyuanhui 中国自然辩证法研究会工程哲学专业委员会 [The Society for the Philosophy of Engineering of Chinese Society for Dialectics of Nature/Philosophy of Nature, Science and Technology]. In parallel but independently, in 2004 the International Network for Engineering Studies (INES) was established in Paris. The informal fPET network took shape in 2010, and Zhongguo kexue jishu shi xuehui gongchengshi zhuanye weiyuanhui 中国科学技术史学会工程史专业委员会 [The Society for the Sociology of Engineering of Chinese Society for the History of Science and Technology] and Zhongguo shehuixuehui gongye shehuixue zhuanye weiyuanhui 中国社会学会工业社会学专业委员会 [The Society for the History of Engineering of Chinese Sociological Association] both came into existence in 2014.

Last, academic journals dedicated to the publication of research in philosophy of engineering have been established. In 2004, *Gongcheng yanjiu: kuaxueke shiye xia de gongcheng* 工程研究: 跨学科视野下的工程 [*Engineering Studies: Engineering in Interdisciplinary Perspectives*], whose editors in chief were Du Cheng 杜澄 and Li Bocong, began publication as a four-volume yearbook (Du & Li, 2004, 2006, 2008, 2009). This publication was expanded into a quarterly in 2009 and a biomonthly in 2016. In 2009, INES published the official journal titled, exactly the same as the Chinese one, *Engineering Studies*, whose editors in chief were, also co-founders of INES, Gary Downey and Juan Lucena. This journal was published three times a year in the first three years and became a quarterly in 2012. Although *Engineering Studies* was not strictly a philosophy journal, it did include philosophical articles. Indeed, as an interdisciplinary effort to bridge history, sociology, and philosophy of engineering it was intimately compatible with Li's vision of what the philosophy of engineering should be.

Together, these four events testify to the international rise of the philosophy of engineering. Nevertheless, it must be admitted that at present the discipline remains in a formative stage. Only continuing joint efforts by philosophers and engineers will bring the philosophy of engineering to maturity.

It was at the SPT conference at the University of North Texas in 2011 that Carl Mitcham introduced Pieter Vermaas, the director of Philosophy of Engineering and Technology book series to Li Bocong and me. Mitcham, as a member of the Editorial Advisory Board of the series, recommended the translation and publication of some of Li's work. At that time, there was not yet a decision about precisely what to translate, but Vermaas expressed his openness to the idea and invited an explicit proposal.

The following year, I began a 15-month postdoctoral residency with Mitcham at the Colorado School of Mines (funded by the Hennebach Program in the Humanities). In the entire process, he helped me greatly, no matter the application and realization of the postdoctoral fellowship, or the research and teaching work at Colorado School of Mines. Mitcham is actually an old acquaintance of Li Bocong having met

when Mitcham first visited China in 1992 for a Sino-American STS Seminar undertaken at the Graduate University of the Chinese Academy of Sciences. The year of 2012 offered me a chance to tell Mitcham about Li's work on the philosophy of engineering, particularly his book *An Introduction to the Philosophy of Engineering*. Mitcham believed that it was quite necessary and meaningful to translate the book into English, which initiated this translation. After counseling with Vermaas, the English translation officially started in 2013. Li Bocong made some additions and deletions to the original Chinese version of the book, while I meanwhile began the translation, along with professor Zhang Shunfu 张顺赴, who retired from the School of Foreign Languages in Sichuan Normal University. English editing of all manuscripts has been done with the assistance of Raymond Porter, who teaches English at UCAS, and academic copyeditors Heather Mowbray and Dorota Niemcewicz.

After more than eight years, the English version is now approaching completion. There are some differences between the English version and the original. In the English version, Chaps. 2–4 are all the same as their Chinese counterparts. However, some cuts have been made to Chap. 1, while Li's views on the engineering community proposed by him since 2004 have been added. Chapter 5 has expanded to include analysis and discussion of interdisciplinary research in engineering and two modes of the philosophy of engineering. When the book was published in Chinese in 2002, Dr. Lu Yongxiang 路甬祥, who was President of Chinese Academy of Sciences, wrote a foreword which is included in the English version. The second foreword in English comes from Li's old acquaintance Carl Mitcham.

The Translator's Introduction is intended to make a brief introduction to the background of both the Chinese and English versions of this book, and the context against and in which the book *An Introduction to the Philosophy of Engineering: I Create, Therefore I Am* has been planned and developed, either mentally in the author's thinking for many years or materially in the form of philosophical literature and scholarship, which has had a great effect on his manuscript. In addition, as his student I believe I am able to contribute to readers' understanding of Li's decades-long endeavor to construct a new philosophical branch, i.e., the philosophy of engineering. I really hope, personally and academically, that this book may offer an insightful and readable introduction to the relatively new subfield of philosophy.

May 2021

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Contents

Chapter 1
Introduction

Abstract The breakthrough came at the beginning of the twenty-first century when the philosophy of engineering was formed in the East and the West in parallel. The twentieth century had been dominated by scholars who claim that engineering is an applied science, concluding that it is impossible and unnecessary to define philosophy of engineering as a new branch of philosophy. Since its inception however, a trichotomy of science, technology, and engineering has been proposed, positing that it is possible and necessary to define philosophy of science, philosophy of technology, and philosophy of engineering as three distinct branches of philosophy. The proposition claims important differences between science, technology, and engineering. The core of scientific activity is discovery, of technological activity invention and of engineering activity "making" or creating artifacts. Scientific activity, technological activity, and engineering activity yield three separate kinds of achievements. Scientific thinking, technological thinking, and engineering thinking are characterized by three different psychological and epistemological thinking styles. Scientific activity, technological activity, and engineering activity should be measured and evaluated by different standards. According to this trichotomy, three branches of philosophy are formed: philosophy of science, philosophy of technology, and philosophy of engineering. Engineering activity is the foundation of human existence and development, and founded upon the maxim for philosophy of engineering: "I create, therefore I am." The establishment of philosophy of engineering means that philosophers are embarking on a Columbian voyage in the world of philosophy. Engineering activities that produce artifacts or daily consumer goods can generally be divided into three phases: planning and decision-making, implementation and operation, and using and living. Thus, research on engineering activities and philosophy of engineering should follow these three phases.

Keyword Philosophy of Engineering · Engineering activity · Trichotomy of Science, Technology, and Engineering · Discovery · Invention · Making or Creating artifacts · I Create, Therefor I Am

B. Li, *An Introduction to the Philosophy of Engineering*, Philosophy of Engineering and Technology 39, https://doi.org/10.1007/978-3-662-64088-3_1

Engineering activities[1] are practical activities that include technical and non-technical factors, including economic, political, social, ethical, ecological, and cultural factors. The content, process and purpose of engineering activities are to design, manufacture, and use various artifacts. These engineering activities are the foundation of social existence and development. The philosophical branch that investigates these engineering activities is philosophy of engineering. Yet, for many reasons, philosophers did not focus their attention on engineering and the philosophy of engineering until the end of the twentieth century.

The philosophy of science is already known as a major part of modern philosophy; philosophy of technology has more recently become a branch of philosophy. The question now is whether or not philosophy of engineering will be the next.

Toward the end of the twentieth century, there was a general call for philosophical investigation into engineering. This appeal came not only from philosophers, but also from engineers. Just as Marx asserted that, "every true philosophy is the intellectual quintessence of its time" (Marx, 1842/2010: 195), the appeal for the birth of a philosophy of engineering clearly reflects the intellectual essence of our time.

Why have Chinese philosophers and engineers called for there to be a philosophy of engineering? The second half of the twentieth century saw vast engineering projects of varying types and forms blossom in China, offering rich experience whether they succeeded or failed. To my opinion, both positive and negative outcomes of engineering projects require philosophical analysis. Indeed, philosophers, engineers, and other researchers should focus on engineering practice, and study the key characteristics of engineering activities, including ontology, epistemology, methodology, axiology, and evolution. They should also examine how engineering practice relates to nature, technology, and society. The philosophy of engineering has justifiably emerged as a new sub-discipline in philosophy. It does not remain in the realm of academia, but rightfully influences the practice of engineering, involving entrepreneurs, engineers, managers, investors, and workers. The core theme of this philosophy of engineering is the production and use of artifacts, a theme not addressed in the history of philosophy to date.

[1] The meaning of engineering can be understood in a broad sense or in a narrow sense. Engineering in a broad sense includes social engineering and material engineering or natural engineering, i.e., engineering that produces artifacts. Engineering in a narrow sense refers only to the latter. Although Roscoe Pound put forward the concept of social engineering long ago and Karl Popper made mention of it, in general, people usually understand the concept in its narrow sense. Natural engineering and social engineering are closely related and yet fundamentally different. The fundamental task of this book is to study natural engineering. Social engineering issues should be addressed in other research.

1.1 Previous Philosophical Attempts to Explore the Theme of Human Creation

Engineering activities, or the human creation of artifacts, are so commonplace that philosophers could not possibly have failed to notice them; objects made by humans are so prevalent that philosophers could not have neglected to use them. On this account, problems that arise from this most human activity, in hindsight, seem to be easily within the grasp of philosophers and ready to be sown in the field of philosophical research. Early in the history of civilization both European and Chinese philosophers investigated the philosophical nature of human creation of artifacts. These investigations established valuable starting points for future philosophical analysis.

1.1.1 European Philosophers' Attempts to Explore the Theme of Human's Creation in History

In *Republic* (Book X), Plato proposed that there are three kinds of beds, and the creation of each was presided over by one of three artists: God, the maker of the bed (i.e., the carpenter), and the painter (597b). Plato conceived that God created the form or the idea of the bed, the carpenter imitated God to make particular beds, and the painter imitated the carpenter. "God, whether from choice or from necessity, made one bed in nature and only one; two or more such ideal beds neither ever have been nor ever will be made by God" (597c). A carpenter, according to Plato's view, may not make an ideal bed, but only some semblance of its existence [which is made by God] (597a). As a philosopher and aesthetician Plato lionized God and the painter, while devaluing the artisan. Nonetheless, Plato's theory of artisans as makers of artifacts should be regarded as a valuable theoretical starting point, a figurative port from which to embark on a voyage into a new philosophical world: the philosophy of engineering. Unfortunately, Plato's inability to embark on this journey himself was a lost opportunity for a new theory on the human creation of artifacts.

In his later years, Plato wrote the dialogue *Timaeus*, in which he attempted once more to explore issues of the physical world. The central theme of *Timaeus*, however, was not the human creation of things, but Plato's philosophy of the god-like Demiurge and the creation of the universe.

Plato was not only a thinker, but also an educator. His most eminent student, Aristotle, proposed a theory with significant implications for future studies on the philosophy of engineering. Aristotle's theory of the Four Causes asserted that any thing came into being because of four causes (*aitia*) or "explanations," namely material cause, formal cause, efficient cause, and final cause. Take a statue of a person, for example. Copper is its material cause, a person's figure is its formal cause, the sculptor is its efficient cause, and carving the statue for someone is its final cause;

or, for instance, in building a house, bricks and tiles are material cause, the design is the formal cause, builders are the efficient cause, and dwelling is the final cause.

Based on the examples Aristotle used to explain his theory of the Four Causes, it seems as if he developed this theory not for all things, or natural objects, but for artifacts made by humans. However, that was not Aristotle's intention. He believed that he had established a theory of physical objects, not just human-made artifacts. From the point of view of philosophy of engineering, however, Aristotle's theory of the Four Causes only considers human-made artifacts.

Plato and Aristotle, the foundational philosophers of Western culture, were standing at the gates of a philosophical theory on the creation of human-made artifacts, but refused to enter. As a result, a theoretical orientation to the theme of human-created artifacts was lost. How should we understand their philosophical neglect of the human creation of artifacts? The root cause may lie in the social environment of Greece in the fifth century BCE. In the slave system of ancient Greece, the scale of material creation had reached such high levels that philosophers were forced to contemplate the creation of things. However, the low status of slaves, usually the creators of the things themselves, meant philosophers could disregard the actual artifact makers, treating them as mere talking tools.

In such a social environment, class status would have likely prevented both Plato and Aristotle from placing a high value on engineering activities, or regarding engineering activities as an important theme for philosophy in itself. For instance, in Plato's *Republic*, artisans and farmers, two groups of citizens who created things, were formed by God from a mixture of iron and bronze instead of gold or silver, and were considered the third estate, endowed with a low social status. Slaves, in Plato's opinion, were merely talking animals. In Aristotle's philosophical theory as a whole, what he was most concerned with was the life and thoughts of leisure-enjoying slave owners and freemen. By contrast, slaves, who toiled to make things, and the relevant philosophical problems related to the human endeavor of making things had little chance to enter his philosophical stage.

The significance of the human creation of objects would not be acknowledged until the late nineteenth and early twentieth centuries. Specifically, the philosophy of technology can be traced back to 1877 when Ernst Kapp published his book *Grundlinien einer Philosophie der Technik [Elements of A Philosophy of Technology] (Kapp 1877/2018)*. Following Kapp, three philosophers titled books with the term "philosophy of technology": Peter K. Engelmeier, Eberhard Zschimmer, and Friedrich Dessauer. Among these philosophers, the most striking figure to arise, especially in terms of philosophy of technology and philosophy of engineering, was Dessauer.

Dessauer believed that in addition to Kant's Three Critiques—*The Critique of Pure Reason*, *The Critique of Practical Reason*, and *The Critique of Judgment*—there should be one more: the critique of technological making (Mitcham, 1994: 29–33). Consequently, Dessauer recommends that philosophers should take upon themselves the fundamental task of critiquing technological making.

While this recommendation is important, Dessauer's own approach is not without limitations. Specifically, in his critique Dessauer simply bundled technology and engineering into one. Furthermore, when he analyzed the philosophical problems of

technology, Dessauer emphasized technological invention, which differs clearly and in many ways from engineering. However, because most inventions are not put into production, the focus of this fourth critique should not stop at technical invention, but should encompass production. From my point of view, engineering is the integration of technical and non-technical factors, and engineering activity is the foundation of social existence and development. Therefore, the fourth critique should be the critique of engineering-making, or creating.

Briefly, modern philosophers have identified a fourth critique that may be added to Kant's philosophical system. From my perspective, writing a fourth critique means establishing a philosophy of engineering.

1.1.2 Chinese Philosophers' Attempts to Explore the Theme of Human's Creation in History

The Chinese Pre-Qin Dynasty, termed the "axial period" by Karl Jaspers, spanned the Spring and Autumn period (770–476 BCE) and the Warring States period (475–221 BCE). This was arguably the most original and creative epoch in the history of Chinese philosophy, a time in which scholars fervently debated a multitude of philosophical issues. The axial period marked the beginning of Chinese philosophical history, and gave rise to major schools of philosophy including Confucianism (*rujia* 儒家), Taoism (*daojia* 道家), Mohism (*mojia* 墨家), Legalism (*fajia*法家), and Logicianism (*mingjia*名家). However, few scholars took an interest in the theme of human creation.

Confucius (孔子), the most influential scholar in Chinese history, clearly disparaged the importance of productive activities. Though he left few words on production, the master was known to have commented that "good work has to be effected with good tools." In fact, this witticism is not about production activities, but a metaphor in response to a question by his disciple Zi Gong (子贡) concerning "benevolence." As the Southern Dynasties scholar Huang Kan (皇侃, 488–545) said of this passage in *Interpreting Analects*, "To practice benevolence, it is necessary to first interpret and clarify its implications by using metaphor…" (Huang Vol 31 Weilinggong I, 2013: 1075). It was obvious to Huang Kan and to later generations of Confucian disciples that what Confucius had taught was not about the importance of human-made things or instruments. Indeed, Confucianism was mainly concerned with moral issues, and elevating the moral realm. To make matters worse, some Confucian masters despised or even opposed technological development, branding advanced technology as a trick or wicked craft.

The theme of human construction and tool use was also neglected in the Daoist philosophy of Laozi (老子) and Zhuangzi (庄子). While Confucius and Mencius (孟子)ignored technology because of their obsession with attaining moral heights, Laozi and Zhuangzi avoided technology because of their strong belief that technology

alienated humans from nature. Vivid analysis of the theme of making things can be found in both Laozi and Zhuangzi. For instance, Laozi said,

> The thirty spokes unite in the one nave; but it is on the empty space (for the axle), that the use of the wheel depends. Clay is fashioned into vessels; but it is on their empty hollowness, that their use depends. The door and windows are cut out (from the walls) to form an apartment; but it is on the empty space (within), that its use depends. Therefore, what has a (positive) existence serves for profitable adaptation, and what has not that for (actual) usefulness (Laozi 1.11).

This might well be the earliest philosophical description and analysis of structure and function of human-made things in the history of Chinese philosophy. Although there are a few dazzling ideas about human-made things and their use in Zhuangzi, they are often mirrored by views that negate and reject them altogether.

Of all the scholars of the pre-Qin Dynasty, it was the Mohists and Xunzi (荀子) who were most concerned with the theme of human-made things. Many scholars regard Mozi (墨子), the founder of the Mohist school, as a scholar trained as a craftsman, steeped in mechanical production. Mozi explained in a chapter entitled "On Standards and Rules":

> Those who work in the world cannot do so without standards and rules. No-one has ever been able to accomplish anything without standards and rules. Even those officers who are generals and ministers all have standards. Even the hundred craftsmen in doing their work all have standards too. The hundred craftsmen make what is square with a square, make what is round with compasses, use a straight edge to establish what is straight, determine the horizontal with a water level, and the vertical with a plumb line. Whether skilled or unskilled, craftsmen all take these five things as standards. Skilled craftsmen are able to comply with these standards whilst unskilled craftsmen, even if they are unable to comply with them, will still surpass themselves if they follow them in their work. Thus the hundred craftsmen all have standards as a basis for their work. Nowadays, the greatest [achievements] is to bring order to the world and the next greatest is to bring order to a large country, but to attempt these things without reliance on standards is to compare unfavorably in wisdom with the hundred craftsmen (Mozi 4.1).

Based on his personal experience as a craftsman, Mozi had come to such a deep understanding of the importance of instruments for making things that he was able to clearly highlight rules for making and using things. Mozi further extended the proposition of "craftsmen following rules" to the generalization that "the hundred craftsmen all have standards as a basis for their work" and "[t]hose who work in the world cannot do so without standards and rules". (4.1).

Mozi's rules and instruments and Aristotle's theory of the Four Causes echo each other at a distance, each illuminating in its own way. The latter is comprehensive, accounting for various elements in the human activity of making things, whereas the former focuses on rules and the function of instruments, emphasizing the utility and use of tools.

Xunzi, living toward the end of the Warring-States period, was well-known for his extraordinary idea that humans should "exploit nature," arguing in his essay "Discourse on Nature," "How can glorifying Heaven and contemplating it, be as good as tending its creatures and regulating them? How can obeying Heaven and