What philosophy can learn from engineering - the impact of emerging technologies on the social world

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Opening Address

ABSTRACT: Until recently philosophy and engineering have had little in common. Philosophy as the most abstract of disciplines did not connect to the hands on practicality of engineering. Engineers had little to do with the world of ideas and philosophy was often disdainful of the mundane projects of engineering. In the present, it is clear that this mutual disregard was both foolish and unfortunate. The extraordinary increase in the power of technology, power which is to a very large degree implemented by engineering, has changed the world philosophy seeks to interpret. More than that it is engineering that is being called upon to offer prudent guidance and undertake responsible means regarding the application of technology to human affairs. Emerging scientific technologies are presenting possibilities to alter the social lifeworld in ways that were hardly thinkable and for which the categories of philosophical ethics are inadequate.

INTRODUCTION

The question, *What can philosophy learn from engineering*? provokes radically disparate responses. It is not simply a matter of philosophers dismissing engineering as concerned with only the most practical and mundane of topics or conversely engineers believing engineering is the corrective philosophers most need to get them out of the ivory tower of the intellect, although each of these responses does possess a degree of credibility. But beyond that, engineers no less than philosophers, have little consensus among themselves about what defines their discipline.

Yet despite the many points of view and general lack of agreement common ground is undeniable: both engineering and philosophy address questions such as *What is the good life?* and *How is one responsible to the community?* as well as scientific questions about structure of the natural world. Indeed, Kant's three great metaphysical questions concerning God, freedom and immortality are also on the engineering agenda. That the approach to all of these, and like questions on the part of engineering, bears no resemblance to that of philosophy in no way implies that engineering is not engaged most seriously in the enduring questions of human kind.

Learned discourse is typically self-referential and this is clearly the case with both philosophy and engineering. Philosophers are often isolated from those in other disciplines that overlap significantly with philosophy and either were historically part of philosophy (such as psychology and mathematics), or fields that also assess the human condition (literature, history and economics for example), as well as those where philosophy has had a long-standing *quarrel* (most prominently politics). Today, we witness the great difficulty experienced by engineers and scientists as they strive to collaborate in areas where emerging technologies transcend the established disciplines. If chemical engineers and chemists or philosophers and psychologists experience difficulty finding common ground, what hope is there for engineers and philosophers to have shared and reciprocal understanding? Why should the effort be made in the first place? Perhaps, as Natasha Mccarthy argues, *the methods and products of engineering can afford enlightenment on problems with which philosophers have grappled for centuries; and engineering can provide a source of novel problems for philosophers to investigate in the future* [1].

The route of this questioning cannot be direct nor can the eventual answer be precise.

Both philosophy and engineering are historical disciplines in the sense that the present state has been largely determined by its history; philosophy makes explicit use of its past whereas engineering tends to regard its history as mostly a curiosity. The importance of this point shall be addressed later. At this stage, it is only noted that philosophy, like science, aims to understand what is regular, to discern an *order of things* whereas history examines what departs from the regular and may be unique. Philosophy has been overwhelmingly concerned with theory - and of course the relation of theory to praxis, while engineering has been practical even to the extent of eschewing theory altogether. There are reasons why these differences can no longer be sustained. The primary reason for this development is the rise of scientific technology, i.e. technology that operates within the fields of scientific investigation, often shaping the contours of scientific inquiry. In the present engineering is an indispensable element of innovation (the economic driver of our day) and innovation in turn is dependent upon scientific discovery. Engineering has thus become a theoretical discipline in ways it never was. This provides a clue to the question under consideration: engineering has become a theoretical discipline grounded in the concrete and often irregular actuality of human concern.

The question *What philosophy can learn from engineering?* therefore, should be revised to read, *What does philosophy need to learn from contemporary engineering?*

To better understand the current conjunction of the practical and the theoretical gaze into the crucible of what might be called engineering thinking or the future of engineering thinking. Here attention is given to some aspects of contemporary engineering education where the boundaries dividing disciplines are being eliminated or at the least redrawn.

EDUCATION: ENGINEERING AND DISCOVERY

Although for some time engineering has been understood as applied science or the application of science to practical matters this is not the same as being scientific or a science and indeed the methods of engineering are often quite unscientific. To understand this difference let us begin with a caricature of the engineering student's intellectual proclivities. Despite engineering's foundation in science and mathematics, students of engineering do not think like theoretical scientists or mathematicians. Likewise, although engineering has roots in craft upcoming engineers in the digital age are more inclined to think in I/O models than extended narrations. Finally, as world makers and maintainers engineers are intimately involved in matters of human choice and preference yet engineering students do not focus on questions of social psychology, aesthetics and value. Of course, this caricature is refuted by numerous exceptions, and the more so as engineers grow in their profession, but it does point to an intellectual trait common to many who are attracted to study engineering. Rather than see this set of dispositions negatively, as something to be overcome by education, consider the virtues of this outlook and in particular the strengths it brings to contexts of problem solving, discovery, innovation and invention.

Since what these activities have in common is the quest for something new the focus here will be on the process of *discovery*. How do discoveries happen? Can one plan to make a discovery or are they always accidents and serendipities? What sort of sagacity is open to discovery? Are the methods of science the prerequisite to discovery? To the latter question the answer is surely *no*. David Hume's famous demonstration of the limitations of inductive prediction, showing that ordinary observation establishes the expectation of the uniformity of nature into the future but not its guarantee and that our knowledge of causation is only habitual opens the door for a critique of science based upon a principle of certainty [2]. If discovery is not a matter of strict adherence to scientific protocols then what is its context?

History tells of numerous discoveries, scientific included, that were pure accident or a result not at all predicted by the investigation. In *The Logic of Scientific Discovery* Sir Karl Popper develops the standard for empirical research known as *falsifiability* [3]. The criterion of falsifiability in contrast to verification or confirmation is based upon the recognition that one can almost always find evidence in support of what one already believes. Yet the principle of falsification does not imply a new method for investigation beyond a protection against the affirmation of inadequate certification of dubious discovery. In a sense the procedure developed by Popper was an empiricist's way of holding onto the Cartesian standard that gave birth to the new science in the era of Copernicus. In his famous *Meditations on First Philosophy* Descartes argued that anything validated simply by the senses might be no more than a figment of the imagination and that even the results of careful rational and mathematical deliberation could be false insofar as they might simply be the extension of axiomatic principles which themselves lacked a guarantee [4]. The results of empirical and rational investigation alike were, without such a guarantee, doubtful. Descartes ultimately found his guarantee in God, thus tying science to a metaphysical system in which the source of certainty rested upon the validity of the ontological argument. From either standpoint the canonical principles of science are instilled with a caution, order and even orthodoxy resistant to radical innovation. To put it another way, scientific revolution - that outpouring of new thinking and discovery - is an aberration or overcoming of science, the throwing out of an established set of principles in favour of a new promise. As purveyors of *the new,* engineers must sustain a tense relationship with science, at once exploiting and eschewing it.

This applies to engineers as discoverers but here engineering is a house divided upon itself. Engineering is characterised by four fairly distinct activities described frequently as CDIO - Conceive, Design, Implement and Operate. Conception, i.e. discovery, differs generically from the other components of engineering. It is with conception that engineering runs afoul of the scientifically biased methods of traditional engineering education.

Perhaps, it is a trifle to assert that engineers harbour little interest in the concerns of epistemology and metaphysics, although, perhaps, it is the case that in its non-discoverer role the quality of engineering practice is proportional to its epistemological rigor. But the larger point is that scientific methodology on the level of justification does not describe the process of discovery and indeed may be incommensurate with that process.

Yet surely discovery is not pure serendipity. It happens in the context of purposeful inquiry, disciplined observation and open receptivity. How can those conditions be fostered in an atmosphere where scientific knowledge is abundant and scientific methodologies fluent?

Is this environment a context for discovery? In his classic short book, *The Tacit Dimension*, chemist turned philosopher Michael Polanyi argues for the rebuttal of exactitude as the ideal of science in order to open the horizons of scientific investigation and to enable the exploration of areas otherwise closed to the scientific mind [5]. In the imagined example above processes are governed by tacit knowledge, yet the conservative goal of replicating the most perfect violin from past production is not open the exploration of alternative ideals. How does Polanyi understand tacit knowledge to broaden horizons and encourage exploration?

He begins by recalling the suppression of pure science under Stalin and the ironic fact that socialist-communist theory proclaimed scientific justification. Stalin may have understood that scientific revolutions could threaten the enforced *revolutionary consciousness* imposed under Soviet rule. Whatever the case Polanyi in a manner similar to Popper saw how a kind of scientific certainty produced dogmatic ideologies. Is there a mode of scientific inquiry that avoids the tyrannical potential of science grounded in a Cartesian-like epistemology of certainty but at the same time does not descend into the closed domain of intuitive understanding where tradition and local approval rule out other modes of empirical confirmation? Would such a mode of inquiry lend itself to discovery? It is Polanyi's position that proper acknowledgement of the tacit dimension does just that.

EMERGENCE

In physics, emergent properties of compound substances are those that cannot be predicted from even the most complete analysis of the physical features of the constituent elements. For example, based upon an analysis of the properties of oxygen and hydrogen, it is possible to predict that they will under suitable conditions combine to form H_2O, but it is not possible to predict that it will be wet. Wet is an emergent property discovered in some way that eludes analysis. The discovery of emergent properties, therefore, amounts to realising when they appear that they are important. This kind of realisation is an act of the imagination. Consider the environment of a modern engineering research laboratory. The experiments, tests and investigations are exercises, based upon scientific knowledge, that seek to confirm a hypothesis. Actually, in many cases what is formally called a hypothesis may be little more than a hunch based upon the investigator's experience working with similar devices or materials. In other words, the basis of the hypothesis is largely a matter of tacit knowledge. In this scenario the use of scientific methods is not abandoned; indeed the appreciation of the potential significance of the emergent property takes place and could only take place in the context of a rigorous scientific inquiry.

The history of science offers an interesting example that can be applied to the question at hand. What we now know as the Copernican revolution, the move in the science of astronomy from a conception of a closed world with the earth as its crowning glory located in the very centre to that of an infinite and open universe where the position of the earth was not special, required both very careful, rigorous and precise measurement and recording of data *and* the freedom of mind to shift completely the theoretical paradigm [6]. It is this latter freedom of mind that emerges from shared experience and reflection, not bound by fidelity to what must be according to the theoretical presuppositions. In the case of the Copernican revolution what was overthrown were metaphysical and epistemological doctrines. Yet there are many ordinary examples where strict allegiance to procedure or precedent blinds one to what may be before his/her eyes. Let us consider again our earlier scenario.

In the shop of the violin master craftsman the enforced discipline was not scientific, indeed scientific knowledge was deemed unnecessary, but rather tacit knowledge crystallised from the past. Indeed, the tacit knowledge that regulated the workshop's procedures and assured the standard of excellence was not really shared as tacit knowledge but was more of a doctrine, passed down and kept as proprietary or private knowledge within the firm. The apprentice craftsmen were told to imitate their masters with the justification that only in this way would the best result be guaranteed. Thus, it is obvious that a dogmatic point of view would effectively inhibit discovery and innovation. On the one hand, the workshop exhibited exemplary engineering and managerial standards, the kind of standards essential to quality control. At the same time, however, these very standards stifled creativity and undermined the possibility of discovery.

This kind of engineering is becoming rapidly outmoded but one may question whether the new, high-tech engineering is the most desirable replacement. To answer this question an inquiry into the values of technology is required.

CONTEMPORARY TECHNOLOGY

For technology limit the scope inquiry to contemporary, scientific technology for it is that which is displacing the importance of tacit knowledge within engineering. The central value of technology, *efficiency*, carries additional weight when understood in the context scientific technology. Heidegger has argued that the Aristotelian concept of the efficient cause has been distorted from a straightforward notion of cause into a metaphysical category to bridge form and matter and to operate within a teleological structure of ultimate purpose. In so doing the very idea of technology is transformed from its original understanding as a revealing, bringing forth or disclosing into something akin to manufacturing. Notions of mass production and industrialisation are supported by this modern distortion of technology and its misplaced emphasis on efficiency in the post Aristotelian sense.

In *The Question Concerning Technology*, Heidegger asserts: *...It is as revealing, and not as manufacturing, that techne is a bringing-forth … Technology comes to presence in the realm where revealing and unconcealment take place, where aletheia, truth, happens* (319). In this initiation, he performs his argument, by bringing-forth the concealed roots of the word *technology*. In doing so, he asserts that modern technology, as with techne, is a bringing-forth, a revealing. Focusing his terminology further, he writes, *...the revealing that rules modern technology is a challenging* (320). Now, Heidegger aligns a slew of terms all of which are modes toward aletheia/veritas/truth – *bringing-forth* [*Her-vor-bringen*] (317), *unconcealment* (317-318), *revealing* [*das Entbergen*] (318), *challenging* [*Herausfordern*]" (320) [7].

Modern, scientific technology exhibits several traits that profoundly differentiate it from pre-scientific technology with respect to human action. The most challenging has to do with the extraordinary increase in power that modern technology can add to even the most innocuous action. Technology then may itself overrule intent and magnify a trivial event into an irreversible calamity. This may happen dramatically in a single episode but more likely and insidiously incrementally, one small change upon another.

ENGINEERING AND TECHNOLOGY

When the results of human action are distanced in time and/or space from the action it is possible to be unaware of the connections. However engineering's use of new technology not only relates humanity to the spatially and temporally distant but also makes possible intimacy previously not contemplated. The traditional understandings of *man and nature* and *man and machine* posited human autonomy and a power relationship with humanity striving for if not always achieving control. The ideal for the human-nature relationship ranged from the Biblical dominion on the part of humanity to the Taoist harmony of the action of non-action. In either case humanity was granted difference and kind of independence from both nature and the artificial world of things. In the present day this ideal is disappearing on both theoretical and practical grounds. This is a profound revolution with engineering on the front lines of the battle.

When considering the role of engineering in advancing new scientific technology the view and analyses of Slavoj Žižek provide much clarification. Žižek discusses trans-humanity, i.e., the interactions across the porous and ambiguous boundary between humans and non-humans including machines and other artificial devices [8]. He traces the trajectory of *technophilia,* the fascination with technology and the belief that it improves the quality of life by increasing leisure and minimising arduous labour, which at early stages may seem benign, from both philosophical and (Lacanian) psychoanalytic standpoints, and concludes - similarly to Heidegger - that the embrace of technology undermines egoic development and the meaning of human endeavour.

Technology has entered our consciousness through popular culture and even appeals to us as a mode of entertainment. Modern technology is no longer merely a tool for which we determine the use. On the contrary, technology determines not only its use but also much else, including emphatically the nature of our engagement and response to it. Consider, for example, the set of interdependent technologies presented by the i-Pad. The i-Pad is simply the latest version of the well-established trend in personal computing where the machine is a single device for entertainment, education, communication, work (e.g. expense accounting) and takes the place of books, newspapers and magazines, cinemas, telephones, conference rooms, recreational venues and yes, personal computers. It has been called a lifestyle device. Indeed there are many individuals now who cannot seem to get along without them. There have been reports of academic retreats where participants have become discernibly anxious when outside a WiFi zone. It is obvious that for many the relationship to an i-Pad or similar piece of equipment is not limited to its utilitarian value. But this has been the case for a long time - consider how most people choose and value their automobile. However, in the case of the i-Pad and like devices there is a greater intimacy such that it actually becomes an extension or fulfilment of the self. In much the same way as a married couple each becomes the extension and completion of the other devices like i-Pads are truly a significant aspect of an individual's personality.

This kind of intimacy with computing devices will only be increased as micro-chips are implanted in our bodies to enhance, augment or replace *normal* functions. The Japanese Buddhist engineer Masahiro Mori has written of what he calls the *uncanny valley*, the term he coined to describe the decline in acceptance and even revulsion most subjects experience to robotic devices as they became more human or at least creature like in their appearance [9]. According to Mori this represented an aversion to permitting machines in the sphere of human interaction. But the phenomenon of the uncanny valley, prominent in the 1990's, has now all but disappeared. The situation now is in fact nearly the opposite as many enthusiastically welcome robots as surrogate care givers (robotic nurses in hospitals), pets (AIBO and PLEØ), sex partners and perhaps even friends [10].

This attitude may be termed *technophilia* and some philosophers like Slavoj Žižek have argued strongly against the trend. What is wrong with this trend? Have engineers unwittingly advanced a pernicious assault on human autonomy?

Or as they generally claim, have engineer's labours in the fields of trans-humanity born fruit to benefit the common good?

There are three parties to this discussion, the conclusions of which are of vital importance for the future: 1) philosophers; 2) pro-technology visionaries; 3) engineers.

Philosophers, East and West, throughout the ages have viewed technology purely in terms of utility. This point of view has extended from Mencius and Lao Tzu to Masahiro Mori and from Plato and Aristotle to Heidegger. With variations philosophy has subordinated technology to a secondary role in human events. Despite the fact that technology has more than anything (consider agriculture and warfare for example) altered the human landscape created the specific possibilities for liberty and freedom of expression, it has been always understood as an expression of mind, dependent upon the direction of the mind. The *problem* of technology has always been an issue of human rationality or understanding.

Technology visionaries emphasise the liberating consequences of technology and the way technology can and does change our lives. There is widespread belief that innovation is a good and that most problems have technological solutions. Technology enhances life, according to this view, by changing it. Technology visionaries deny the random aspect of evolution (a key element in Darwin's theory) and see technology as enabling progression toward a higher order future. In this view we can look forward to a better nature (genetically engineered foods), better health (the expectation of the human genome project), better *more liveable* homes, and untold amusements ready at hand. Into this scenario are introduced intimations of immortality, universal peace and the absence of all unpleasant arduous work. This utopian faith in the unbounded good of technology is indeed a religious quest.

Engineers tend to be far more sober than technology visionaries, their frequent collaborators. Engineers are partners in the process of innovation and colleagues in the work of scientific discovery. Yet much of engineering must focus on maintenance, on the care for the built world that exists, and the day-to-day operation of highly complex devices, the reliable functioning of which is essential to human thriving. If the CDIO paradigm characterises accurately engineering practice, then, it is clear that the unbridled optimism of technology visionaries has not been embraced. The philosopher's question of human understanding and rationality corresponds more closely to the engineer's outlook, however for the engineer human rationality is never exhausted by information science or abstract symbol systems of any sort.

CONCLUSION: WHAT PHILOSOPHY *MUST* LEARN FROM ENGINEERING

In the present day engineers address challenges of deep philosophical and ethical import. They are doing so, together with common sense, tutored only in the pragmatics of engineering itself. Thus, engineering is doing philosophy although engineers might be loath to say so. And indeed engineering is not prepared to understand some of the dimensions and consequences of its own effort. Particularly in the brave new world of such possibilities as trans-human identity engineers need to engage with philosophers. But for this to happen philosophy needs to learn lean a number of recent lessons from engineering.

Engineering is largely a practice, pragmatically oriented and grounded in the realities of material existence. Although natural science is a foundation for much of engineering, discovery is facilitated by tacit knowledge. Open tacit knowledge, at once experiential and social, guides engineers in their double-pronged task of discovery and maintenance. The engineering approach to discovery is an epistemological position that bridges the artificial mind-body dualism of much philosophical metaphysics. Maintenance corresponds to Heidegger's category of care and is a concrete ethics of responsibility.

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