Philosophy of Technology: Themes and Topics

2

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Abstract
Main themes in current philosophy of technology are the nature of technical artifacts, the nature of technological knowledge, the nature of models in technology and engineering, and norms and values in technology. These are studied in the context of an "empirical turn" that took place in philosophy of technology. A next step in this discipline will probably be an axiological turn.

Keywords
Philosophy of technology • Knowledge • Modeling • Normativity

Contents

Introduction

Although the philosophy of technology was a relative latecomer in the philosophies of specific human scientific and cultural activities, it has become a well-established academic domain. It aims at systematic reflection on technology. The purpose of such reflections can be purely theoretical, but philosophers of technology also try to

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be in contact with practitioners in technology in order to find out what conceptual and critical analyses can be of use for them. Technology educators also are potential users of their work. The aim of this chapter is to provide a concise survey of what has been developed so far in the philosophy of technology in terms of ideas about the nature of technology. Introduction of philosophy of technology is often based on the fourfold ways of conceptualizing technology as presented by Carl Mitcham in his well-known book *Thinking Through Technology*. Because several such texts exist already, I will use a different basis for a survey of the philosophy of technology, namely, the Handbook *Philosophy of Technology and Engineering Sciences*, edited by Anthonie Meijers. This handbook is more recent (2009) than Mitcham's "classic" book (1994), so it provides a more up-to-date overview of where philosophy of technology stands now.

There are clear communalities between Mitcham's four ways of conceptualizing technology and the section headings in Meijers' Handbook. Mitcham identifies the following four ways of thinking through technology as a set of artifacts, as a knowledge domain, as a set of activities (designing, making), and as a feature of humans and society ("homo technologicus," the "technological society"). Both Mitcham and Meijers have artifacts, knowledge, and design as major structuring elements in their surveys. The fourth Mitcham element (the human and social dimension) are also present in Meijers' Handbook but more focused on ethics and values. Meijers has a separate section that is dedicated to models in engineering, which is an issue that Mitcham did not pay much attention to, and understandably so because in 1994, not much had yet been published about that in the philosophy of technology. Also new in the Meijers Handbook is the extensive attention for engineering sciences. Mitcham did write about the relation between technology/engineering and natural sciences, but not much about the nature of engineering, which, again, is a matter of timing, as the philosophy of engineering science is one of the latest developments in philosophy of technology.

Following Meijers division in sections, I will present the survey of philosophy of technology for this handbook in the following way: I will first discuss the struggle to define technology, engineering, and engineering sciences. Then I will continue with a more or less "standard" element in the philosophy of technology: the reflections on the nature of technological knowledge. I will skip the reflection on the nature of artifacts (particularly the dual nature approach as developed in Delft, the Netherlands, as that has already been described extensively elsewhere). As suggested by the Meijers Handbook, I will pay separate attention to models and modeling in technology. Modeling is also one of the most prominent concepts that came out of a Delphi study into relevant concepts for technology and engineering education. Then the ethical issues will be discussed, starting from reflections on technological normativity in general. In the final section, I will briefly indicate how the future of philosophy of technology would fit best with the needs of technology education.

Defining Technology and Engineering

In his introductory chapter for the Handbook of *Philosophy of Technology and Engineering Sciences*, Anthonie Meijers shows that both the term “technology” and the term “engineering” originate from words that indicate a practice-oriented type of knowledge. The Greek word τέχνη in Plato’s later works referred to knowledge related to making. The Latin word *ingenera* meant to generate or produce, and the term “engineering” indicated the discipline of generating or producing (Meijers 2009). In the course of time, the notions associated with these terms have shifted. Technology is generally seen as the development and use of the enormous variety of artifacts and systems that we find around us. The impact of this on our lives is so important that we speak of “technological literacy” as a requirement for every citizen that should be learned at school. Not all people, though, need to be educated in technology in order to participate in the development of new artifacts and systems. That is, not all people need to become engineers. Engineering is nowadays seen as the professional domain related to technological development. Another related term is engineering sciences. That is the systematic acquisition of knowledge that is needed for engineering. Engineering sciences are similar to natural sciences in that they have processes for assessing whether or not the produced knowledge can be regarded to be “scientific.” But in the natural sciences, the main criterion is the likeliness between the developed knowledge (in the shape of formulas, theories, and models) and the observed reality (“truth”), and in engineering sciences, the main criterion is “proven usefulness.”

Apart from these theoretical perspectives on technology and engineering, there are general perceptions of what they are. Carl Mitcham has presented a set of four different ways in which people can perceive technology (Mitcham 1994). This set has been used widely by other philosophers of technology and in the context of technology education. The way of seeing technology is as the whole collection of artifacts and systems around us. When we say that we use “technology” to communicate, move around, prepare food, etc., then in fact we mean all these artifacts and systems. The second perspective is that of knowledge: technology as something you can learn and study. For a long time, the “technology as applied science” paradigm has blocked our view on this perspective. Now we realize that technology does have its own knowledge content and there is more at stake than just applying the knowledge that science has produced. The third way of seeing technology is that of processes: technology as something you do. This comprises designing/developing, making/producing, and using/evaluating. The fourth perspective on technology is that of the human and social value we see in changing the world around us: technology as something that you are (“homo technologicus”). This is where ethics of technology enters the scene. It is also the way STS (science, technology, society) studies perceived technology.

Technological Knowledge and Relations with Natural Science

In his contribution on the nature of technological knowledge in the Meijers Handbook, Wybo Houkes gives a survey of the problems one runs into when trying to identify distinct characteristics of technology (Houkes 2009). Meijers and de Vries in the *Companion to Philosophy of Technology*, edited by Jan Kyrre Berg Olson and others, list four of such possible characteristics (Meijers and de Vries 2009): (1) the context-dependent nature of technological knowledge, (2) the often nonpropositional nature of technological knowledge, (3) agreements as an origin for technological knowledge (e.g., agreements on technical standards), and (4) normativity in technological knowledge. The last-mentioned feature is one that Houkes sees as perhaps the most promising for being distinctively technological and different from science knowledge. Normativity features in various forms: in technical standards, rules of thumb, good practices, and also functions. Functions are particularly interesting as they play a key role in engineering and have a normative nature in that they do not describe what the artifact actually does but what it should do. A car has the function of bringing me from A to B, even when it is in the garage for repair and cannot bring me from A to B. If the notion function was descriptive, the broken car would have lost its function, but due to the normative character of functions, it has not. This normativity is related to the context relatedness that is claimed by Meijers and de Vries, as what is useful in one context may not be in a different context. Also the notion of agreements as a source of knowledge is related to this normativity and what should be can be agreed on freely, as an agreement on what is should always be based on a discussion in which arguments about the fit between the claimed knowledge and reality is crucial. So the normativity in technological knowledge seems to be a core feature in knowledge that is present in technological knowledge and not in, e.g., natural sciences.

Normativity also features in reasoning in engineering. Reasoning is an epistemic activity that is very important, both in natural science and engineering. Much reasoning in natural sciences is cause-effect reasoning. That is the type of reasoning that enables a scientist to derive from a hypothesis what will happen in an experiment if the hypothesis is correct. It runs like: if I switch on the experiment, then this and that will happen. In technology this type of reasoning is also used, namely, to derive from the realized product or prototype what its behavior will be when I put it into use (switch it on or whatever). In other words: the functioning of a device can be derived from its physical realization by cause-effect reasoning. Note that this is not the same as its function. I can derive from the physical realization of an old-fashioned light bulb that it will generate both light and heat when I switch it on. That is its functioning. But that still leaves the options of using it primarily as a light source or a heat source. To identity relations between physical realization and function, I need a different type of reasoning: means-ends reasoning (Hughes 2013). This type of reasoning is not deductive like cause-effect reasoning mostly is, and therefore it is not one to one (one functioning uniquely related to one physical realization). For one means, I can think of different ends, and for one end, I can think of different means. Means cannot deductively be derived from ends and vice versa. Means-ends reasoning does feature also in natural sciences but in a different way. Explanations ("theories") cannot be deductively derived from phenomena and vice versa. That can be understood when we realize that in fact theories are a sort of equivalent of artifacts in science: they are human constructs for a certain purpose (explaining the observed phenomenon).

Models and Modeling

As Sjoerd Zwart in his introduction to Part IV of Meijers' Handbook indicates, modeling in engineering has a characteristic that makes it different from modeling in natural sciences: the purpose of contributing to the development of new artifacts and systems (Zwart 2009). In natural sciences, models only play a role in developing knowledge about reality (as it is, not as we would like it to be, as in technology and engineering) (Zwart 2009). In natural science, models can even be a goal in themselves because they provide an understanding of reality, at least in a simplified version (but this is always the case in natural science). In engineering, models always feature in the process of technological innovations, but still they can have different functions, depending on the phase in which they feature. In the early phase of design, engineers can use, for instance, conceptual models of an artifact-in-design, like a system representation. Such a model helps designers to figure out the structure of the system: how should different components be related so that the system as a whole will fulfill the overall function? Also for planning the whole design process, a conceptual model can be used. Such a model represents the consecutive phases of the design process. Later on in the design process, models can be used to communicate with customers and/or users. Architects, for instance, make a physical model of a house to demonstrate to the client what the house will look like. Physical models can also have a more dynamic character. Sometimes engineers want to show the functioning of a device-in-design, and they make a model that contains not just the shape of the device but also can fulfill its function (though often in a simplified mode). For simulating the functioning of an artifact-in-design, also formal models are used. These models consist of symbols. Those can be the 0's and 1's in a computer model, but also formulas are an example of formal models. In engineering we find formal models in the form of, e.g., CAD and CAM models, FEM models, and numerous other models in which a process is simulated in a computer. FEM models are an example of a model that heavily leans on natural science models. The behavior of, let us say, an engine-in-design is simulated in a FEM model by using the formulas for relations between stress, heat, and forces as they have been found in natural science.

An important feature of models in engineering is that they can have a normative character: they do not represent a simplified version of the world as it is but as how we want it to become. In fact, this is the way we use the term "model" sometimes in daily life also: a "model" teacher or pupils. By that we mean a teacher or pupils as we would like them all to be, even if that model does not even refer to a real teacher or pupils, but one that we imagine. In engineering models, normative models are widely used. Some examples were mentioned already before: the model that represents a system-in-design and the model of the "ideal" design process. This normative character of models is related to the normativity that also features in engineering knowledge. Boon and Knuuttila call models "epistemic tools" (Boon and Knuuttila 2009; see also the section on technological knowledge in this chapter).

Modeling is the process of creating a model. Almost by definition, this process entails abstraction. This term literally means peeling off, and it is used to indicate that certain aspects of a situation are left out. In a certain way, this is the very basis of any type of science: by focusing on one aspect of reality (e.g., the physical aspect, the economic aspect, or the social) and leaving out all others, a scientific discipline can investigate that aspect in depth without being "distracted" by the other aspects. Also within a scientific aspect, abstraction takes place, for instance, when friction is left out. Leaving out whole aspects of reality is done also in engineering sciences but less so than in engineering. This is because leaving out aspects of reality is not problematic for just studying the situation, but it will be when we want to interfere with reality, because then all the aspects of reality need to be taken into account as they all play a role in the failure or success of the product. An engineer cannot afford to focus only on the physical aspect of the artifact (s)he designs, as it can only be successful if it does not only fit with the "laws" of the physical aspect of reality but also with the constraints that are generated by the psychic aspect (how users will perceive the artifact), the economic (what they are prepared to pay for it), and the legal (is there a patent that can be infringed?), just to mention a few of the other relevant aspects. This is why engineers in particular have to be aware of the differences between their models and the real world. An example of this is using model airplanes in a wind tunnel. In reality the ratio between the size of the air molecules and the plane is different than in the wind tunnel situation as the plane is much smaller and the air molecules have their normal size. In choosing what from reality to keep and what to leave out in the model, analogies play a role. Analogies are certain features in reality that are kept in the model, while others are left out. An electric circuit can be used as a model for a water circuit as it has elements that are analogous to those in the water circuit (e.g., a battery in an electric circuit is analogous to a water pump in the water circuit). Engineers can use such analogies to develop models. Different types of analogies can be distinguished. The function of a part in a device can be analogous to a part in a different device (as in the example with the battery and pump). But also the shape of a part can be analogous in that of a different part. For instance, the shape of a wheel is analogous to the shape of a CD. That creates the possibility of modeling a car by using CDs instead of real wheels. Also the configuration of a system can be analogous. The configuration of an electrical circuit (with a battery, a switch, and some resistors can be analogous to a central heating system with a water pump, a water switch, and radiators).

Apart from abstraction, idealization is a tool for modeling. Idealization is not leaving out something but changing (usually changing something irregular to something regular). This is what engineers do when they go from a measured curve in a graph to one that fits with a mathematical formula. This approximation enables them to use mathematics to manipulate the data and make predictions. Idealization for modeling purposes often builds the bridge between data and mathematics.

Norms and Values

Traditionally, ethics has been an important domain within the philosophy of technology. Particularly philosophers in the Continental line have contributed to this. Prominent names are Don Ihde, Andrew Feenberg, Albert Borgmann, and Langdon Winner. Their ideas have been described in previous reviews of philosophy of technology literature (Vries 2016; Verkerk et al. 2016). Ethics is the field where norms and values play a dominant role. As Van de Poel argues in his introductory chapter to the Norms and Values section in Meijer's Handbook, there are several ways of showing that technology is inherently value laden. Perhaps the most basic way is to claim that proper functioning is a value in itself. But most philosophers see that as a variant of the claim that technology is in fact neutral and that it is the user who determines for what values artifacts are used, for good, or for bad purposes. Obviously stating that the drilling machine functions well is a value statement. But it is still way from what non-philosophers tend to see values, namely, ethical values. Perhaps the small distance between the functioning value and the ethical value can be illustrated by asking the question what it means when we say that "this is a good car?" It can have a purely functional meaning: it is suitable for bringing me from A to B. But the way the car does this is not far from this meaning: it may be good in bridging the distance, but I feel totally shaken when I exit the car again. So comfort may also be seen as part of the claim that "this is a good car." But that is not far from a next claim: it brings me from A to B in a safe way. And this again can be seen as close to: it is not only safe for the people inside the car but also for the pedestrians and other people outside the car. And it does not pollute more than necessary. By then we have already entered the domain of ethical values. In a similar way, the same can be shown for norms. Norms are in fact a sort of concretization of values. A norm related to the function of bringing me from A to B can be the desired range of the car: what is the distance that I can travel with a full tank of fuel?

Van de Poel also shows that there are not only values and standard related to technical artifacts but also to technological practices (Van de Poel 2009). I can think that he or she is a "good" engineer. What does that mean? Here we can go through a similar range of meanings, starting from "(s)he is good in developing artefacts" to "(s)he is a morally good engineer." Practices are a philosophical concept that is very useful to illustrate the role of values and norms in technology. This concept was used by ethicist Alasdair MacIntyre to provide a new impetus for virtue ethics (MacIntyre 1981). Aristotle, one of the founding fathers of this type of ethics, always asked the question: what would a good human do? MacIntyre argues that this question needs to be refined: what would a good teacher do, what would a good judge do, what would a good engineer do, etc. Each of these functions in a particular "practice" with its own norms and values. Those determine what is good and bad. A surgeon and a butcher both cut in meat. But cutting meat morally good means different things in the different practice in which they function. For a butcher, it is morally wrong to cut in such a way that a lot of meat is wasted unnecessarily. For a surgeon, it is morally wrong to cut in such a way that the patient will be left with visible scars and tissue damage. Likewise what is morally good for engineers is determined by the norms and values that hold in the engineering practice. Several types of norms can be distinguished: norms that define the practice (e.g., what it means to be a certified engineer) and norms that are related to the higher goals of engineering (e.g., norms for sustainable engineering). The former can be called constitutive or structural norms, and the latter can be called regulative or directional norms.

A challenge to the discussion on norms and values in technology is that this practice is a multi-actor practice. Often many stakeholders are involved, each with their own practice and related norms and values. When an industrial company and a government work together on stimulating a certain technological development, they have both different constitutive and different regulative rules. Governments have different tasks and responsibilities (those are examples of constitutive norms) than business people. Likewise they have different higher values (e.g., public justice for a government and making money for a company). Clashing norms between different practices can hamper technological developments. But also clashes of norms within a practice can cause problems. When an industrial company has customer satisfaction as a regulative rule, but there is no department or there are no individuals that have a responsibility for dealing with customer requirements and concerns (a lack of constitutive norms related to the claimed regulative norm), this will not work. Another challenge that comes with the multi-actor character in technological developments is the problem of responsibilities. This is sometimes called the “many hands” problem or the issue of collective responsibility. When a company produces a car that is inherently dangerous (like the famous and “classic” Ford Pinto case that features in many books for engineering ethics), this is the result of decisions taken by engineers, managers, technicians, etc. It is difficult to tell whom to blame when something goes wrong with those cars, as many people were involved and each of them contributed in his/her own way to the overall outcome of a dangerous car being produced and sold.

The designing of an artifact has everything to do with values. Whether or not the car is a “good” car in the wide sense of the term is largely determined in the design process (not only, because the way the car is used also determines whether or not it is a good car in the wide sense). The challenge for designers is to “translate” values into the physical realization of the artifact. Some philosophers claim that thus the artifact becomes a moral actor as it influences the behavior of the user also in a moral sense (Verbeek 2014). The speed bump that slows down traffic in a residential area forces the driver to behave morally well (at least, as far as traffic safety is concerned) in that area. Likewise it is possible to design cars that simply do not start when the inbuilt sensor “smells” that the alcohol percentage in your breath is too high. Technically speaking this is very simple, but as a society, we are still inclined to leave responsibility with humans and not delegate that to devices as they cannot be held responsible because they lack freedom of choice (one of the conditions for moral responsibility, next to knowledge of norms and knowledge of the situation). Design processes in which a systematic reflection on values is an integrated element are called value-sensitive design. The focus on values is one that may become even more important in the future of philosophy of technology that it currently is already. I will now turn to that perspective.

Conclusion

In the 1990s, the philosophy of technology went through what was called “an empirical turn.” This turn was introduced in a seminar that was organized by Kroes and Meijers in Delft, the Netherlands. In 2016, Kroes and Meijers proposed a next turn for the philosophy of technology: an axiological turn. Axiology is the sub-domain in philosophy that is concerned with values. As was described in the previous section, values did already play a role in philosophy of technology. Kroes’ and Meijers’ proposal is to enhance that role. They are motivated by the fact that by taking this “turn,” the philosophy of technology can become (even) more relevant in social debates about new technologies. A fundamental reflection on the nature of the values that are at stake in new technologies could be a valuable support for the development of such technologies but also for responsible use and for policy making with respect to such technologies. This would be different from an “applied” turn in which philosophers would only deal with practical issues concerning values. It is the philosophers’ task to focus on more fundamental reflections and for the values discussion the importance of such reflections can hardly be overestimated. Hansson also suggested seeking a broader embedding for the philosophy of technology. Normativity and value issues are also found in other domains in which humans intervene in reality (such as medicine). According to Hansson, the Middle Age concept of “mechanical arts” would be worth revisiting and used as a broader context for the philosophy of technology (Hansson 2016). The axiological turn can also be part of a “social turn” in the philosophy of technology, as suggested by Breij. Such a turn would require more intense collaboration with relevant social actors (industries, governments, users). At the same time, the relation with “hard-core” philosophy must not be forgotten, according to Pitt (Pitt 2016).

Seen from the perspective of technology education as a “user” of philosophy of technology, it would be good if the philosophy of technology keeps the broad perspective that it had so far. On the one hand, more and more attention is paid to concept learning in technology education (see ▶ Chap. 8, “Technology Education: An International History” in this volume), which could benefit from the more analytical approach in the philosophy of technology (reflection on the nature of artifacts, design, values, etc.) as proposed by Kroes and Meijers (Kroes and Meijers 2016). On the other hand, the importance of technological literacy as a goal in technology education would benefit from a (continued) attention for the interaction between social and technological developments, as in the “social turn” proposed by Breij (Breij 2016). Of course technology educators are not in the position to determine the future of philosophy of technology, but if relevance is a criterion for future philosophy of technology, then the impact on technology education should be seen as one type of relevance that is perhaps even important as the relevance for engineers and policy makers. The philosophy of technology has a great potential to provide a sound conceptual basis for technology education if both philosophers of technology and technology educators recognize that potential and use it to make strategic choices for the future of their disciplines.

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