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Research article

A Call for Technological Understanding

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Abstract

The daily experience of multistabilities of technical artefacts gives rise to the question of how we can make sense of them in the interaction. A historical and ontological review reveals that technology provides a more primordial way of knowing than science. A comparison between explanation and understanding in science demonstrates that a scientific explanation alone is insufficient for the acquisition of all knowledge. Achieving scientific understanding requires a confluence of a scientific explanation, human agency and social context. Having emerged as a key issue within the engineering-oriented philosophy of technology, the shared consensus of researches on technological explanation is that deductive reasoning is insufficient for producing a comprehensive explanation of function in terms of physical structure. Based on the pervious discussions, I introduce the notion "technological understanding" referring to sense-making in the interaction with technical artefacts in this paper. This understanding is unfixed and involves primitive, context-sensitive, re-interpretative and history-situated sense-making. A theory of technological understanding as a comprehensive exploration of human cognition should take all the conditions and factors of understanding into account. A preliminary analysis indicates that the affordances of a technical artefact, context and human agency are essential components for the technological understanding. In addition, the acknowledgement of and concern with sense-making of situated, context-sensitive meanings align with the core of hermeneutics. Therefore, taking hermeneutics of technology into account may provide productive insights for exploring technological understanding.

Keywords: Technological Understanding; Technological Explanation; Multistabilities of Technical Artefacts; Hermeneutics of Technology; Engineering design

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Научная статья

Призыв к технологическому пониманию

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Аннотация

Повседневный опыт мультистабильности технических артефактов порождает вопрос о том, как мы можем осмыслить их во взаимодействии. Исторический и онтологический обзор показывает, что технология обеспечивает более исконный способ познания, чем наука. Сравнение объяснения и понимания в науке показывает, что одного научного объяснения недостаточно для приобретения всего знания. Достижение научного понимания требует слияния научного объяснения, человеческого фактора и социального контекста. Возникнув как ключевой вопрос в инженерно-ориентированной философии технологии, общий консенсус исследователей технологического объяснения заключается в том, что дедуктивное рассуждение недостаточно для создания всеобъемлющего объяснения функции с точки зрения физической структуры. Основываясь на предыдущих обсуждениях, я ввожу понятие “технологическое понимание”, относящееся к созданию смысла во взаимодействии с техническими артефактами в этой статье. Это понимание не фиксировано и включает примитивное, контекстно-зависимое, реинтерпретационное и исторически обусловленное создание смысла. Теория технологического понимания как всеобъемлющее исследование человеческого познания должна учитывать все условия и факторы понимания. Предварительный анализ показывает, что возможности технического артефакта, контекста и человеческого фактора являются существенными компонентами для технологического понимания. Кроме того, признание и озабоченность смыслообразованием ситуативных, контекстно-зависимых значений согласуются с ядром герменевтики. Таким образом, учет герменевтики технологий может обеспечить продуктивные идеи для изучения технологического понимания.

Ключевые слова: Технологическое понимание; Технологическое объяснение; Мультистабильность технических артефактов; Герменевтика технологий; Инженерное проектирование

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INTRODUCTION

This may be a shared experience of the multistabilities of a single piece of artefact: when we sit on the floor, a chair can turn into a table; or the handles of a treadmill can do excellent work as clothes hangers. Numerous comparable examples can be found within broader cultural contexts as well: an Indian prayer wheel is transformed into a windmill in Western culture, and sardine cans are worn as fashionable decorations among the New Guineans. The usage and impact of a given product may vary significantly across different social and cultural environments. This "ambiguity of technology" has been considered cultural hermeneutics by Don Ihde (1990). It raises the question of which forces contribute to the transformation of purpose or utility.

Chair, treadmill, and prayer wheel are all technical artefacts. They are products from technological industries and material embodiments of technology. Given the importance of technology and technical artefacts in modern societies, it would be unimaginable to live in a world without them. Therefore, the scenario outlined above is a recurring phenomenon in our daily lives. In effect, it is an issue concerning understanding. If the different ways of grasping and using the same technical artefact should not be viewed as totally arbitrary, which factors affect our understanding of these technologies? If there are none too many accounts of "technological understanding," however, this may owe to the long-standing neglect of technology when it was classified for a long time as subordinate to science and scientific understanding.

This paper is a call for increased attention to the conception of "technological understanding." It proceeds in three steps: first, a justification for technology as a primordial way of knowing; second, an analysis and comparison of explanation and understanding in science as a backdrop for the following investigation; third, a call for accounts of technological understanding in contrast to technological explanation, with a preliminary review and exploration of the factors that are relevant for their comparison.

TECHNOLOGY: A MORE PRIMORDIAL WAY OF KNOWING

Speaking of technology, people immediately associate it with science. The phrase "science and technology" with the connection and hierarchy embedded are so deeply ingrained in people's minds, that it seems as they two are born together as a big brother "science" and the little brother "technology."

The motto attributed to Francis Bacon, "Scientia potentia est" ("Knowledge is power"), reflects the recognition of modern science and the desire in Western thought to harness its power and gain mastery of nature. Science is viewed as an objective approach to discover true knowledge about nature. Scientists work in their laboratories, making experiments and creating mathematical simulations to deliver explanations of natural phenomena and establish laws of nature. Modern science establishes a clear dichotomy between the observer (human) and the observed (object), seeking to eliminate all human factors, purifying and reducing experiences in our lifeworld to formal and mathematical terms. It is a structural description of the real world. From this perspective, scientific knowledge is conceived as entirely pure and objective, devoid of any social or human influence.

It is undeniable that natural science has achieved remarkable success and has indeed made significant contributions to the development of humankind. This success, in turn, consolidates the noble status of science and draws many advocates. Scientism and related perspectives such as positivism and scientific realism wholeheartedly endorse science. Scientism privileges science as the most valuable source of insight and learning which can uncover the truth behind the phenomena (Sorell, 2013). This science-centric trend has also influenced disciplines like sociology. These often adopt quantitative methods such as quantitative analysis in an effort to establish themselves as a science. Likewise, positivism is a philosophical school that regards scientific verification as the foundation of all knowledge.

When our analysis turns to technology, we will see that its conceptual status remains unsettled. Normally, technology is viewed as a derivative of science. Gardner summarized this position as “technology-as-applied-science (TAS).” It is “the idea that technological innovations can be seen as the application and practical embodiment of ideas first gained through scientific research” (Gardner, 1994, p. 133). Bacon is often taken as an early proponent of TAS, because he believes that science can facilitate the development of technology. He places a high value on the immense power of technology for human to take mastery over nature: “the true and lawful goal of the sciences is none other than this: that human life be endowed with new discoveries and power” (Bacon, 1620/2000, p 66). Mario Bunge is another famous representative of TAS. He supports the distinction between pure science and applied science, and identifies technology with applied science. For him, the pure cognitive pursuit will aim toward pure science, while a fundamentally practice-oriented goal gives rise to applied science (Bunge, 1966).[1] Science provides the theoretical part and technology the practical; science strives for eternal truth while technology is to solve problems. It is that “scientific ideas have been the main motor and technology their beneficiary” (Bunge, 1966, p. 330). The TAS idea illuminates the dependence of technology on science. The scenario is that stable knowledge comes from scientific research and then technology takes advantage of it. In this case, technology is not only entangled with science but also takes a subsidiary role within a hierarchical order that assigns primacy to science.

Even though TAS has long been dominant and remains highly influential to this day, other thinkers have taken different positions. It is readily apparent that the manipulation of tools dates back to the very beginning of human existence. The basis of human’s survival consists in the ability to cope with various obstacles we confront in the natural environment (Lindberg, 2010). In order to survive we need to create conditions for ourselves by making use of the resources we can find. All those necessary activities and creations for living have finally grown to crafts, techniques, and eventually to contemporary highly advanced technology. The history of using and producing tools of “homo faber” is much longer than the doing of science which has a history of only 3000 years (Niiniluoto, 2016). Based on statistical methods, Derek de Solla Price drew the

[1] According to Carl Mitcham, Bunge’s paper with the title “Toward a Philosophy of Technology” was the first time that the phrase “philosophy of technology” came to the fore in English (Mitcham, 1994, pp. 36-37). However, Bunge only views technological knowledge as “an outcome of the application of the method of science to practical problems” (Bunge, 1966, p. 331).

conclusion that science and technology have separate structures and independent patterns of cumulation in their knowledge development (de Solla Price, 1965). There is in this picture no direct flow of impact in both directions except in some special and unsettling cases like what Thomas Kuhn calls paradigm shifts (Kuhn, 1997). Thus, it is wrong to see technologies as applications of scientific discoveries. From researches in history of science, Kuhn observes that "(s)cience and technology had been separate enterprises before Bacon announced their marriage in the beginning of the seventeenth century, and they continued separate for almost three centuries more" (Kuhn, 1971, p. 284). Many technological innovations are independent of and even prior to science. This holds not only in Western contexts. Song Yingxing, a Chinese scholar in the Song Dynasty, held that cosmological knowledge and universal principles are embedded in the processes of everyday crafting and technique. His book *Tiangong kaiwu* sets out to demonstrate how this knowledge functions as models that guide how people should behave themselves (Song, 2011). This systematic search "for a rational order in the world" aligns with the modern conception of a natural scientist (Schäfer, 2019, p. 54). Though coming from various backgrounds, these thinkers articulate a shared view from the historical aspect that doing technology can produce its own knowledge which is independent of doing science (also, for example, Arthur, 2009; Layton, 1974; Mitcham, 1994; Vincenti, 1990).

Heidegger's (1927/1962) analysis makes him a representative for an ontological defense of the primacy of technology. In his early work *Being and Time*, his examination of ready-to-hand (*zuhanden*) and present-at-hand (*vorhanden*) entities reveals that in manipulating technical apparatus there exists a primordial mode of knowing. This kind of knowing is not a theoretical cognitive process, it is the initial grasping of the living and "furry" reality through using, producing, and manipulating – far before a theoretical thematization of the world. It is an engaged, pre-scientific, and existential form of knowing. In *The Question Concerning Technology*, Heidegger (1977) defines technology as a mode of revealing, a bringing-forth (*poiesīs*) that "brings out of concealment into unconcealment", a realm in which truth is disclosed (p. 308). He is among a group of philosophers who assert the opposite: Modern science is based on modern technology, as the development of science relies on the state of technology (see, for example, Arthur, 2009; Heidegger, 1977; Ihde, 2010). The reason why modern technology no longer serves as a bringing-forth, but rather as enframing (*Gestell*) is that modern technology no longer reveals things in the mode of bringing-forth. In the contrast, it challenges nature and humankind into standing reserves. "Seeing" through the lens of modern technology provides modern science with "calculative thinking." All the living and furry flesh of reality is wiped away after this process, only the results of calculation remain. Combining Heidegger's ontological analysis and Lynn White's historical insights, Don Ihde (2010) articulates the claim that "the historical-ontological priority of technology as a condition of the possibility of science" (p.57).

In light of the above discussions, I would maintain that doing technology is actually a more primordial way of knowing the world than doing science. Science is viewed as a systematic pursuit of knowledge, is an abstract thematization, a mathematization of the real world. It displaces the phenomenal world by mathematical models that are to observe and handle. Scientific practice abstracts formal models from the richness of the empirical world, reducing living materials such as soil and leaves into numbers and statistical tables (Latour, 1999). Through that, the natural phenomenon is mathematized, calculated, mimicked and manipulated, the lifeworld in which we live in with all the living entities disappears, while a purely scientific world is constructed. This differs from how we interact with technical artefacts. We do not mathematize the artefacts when we use a tool, only manipulate and experience them with our bodies and limbs. Although we sometimes require mathematized information such as the precise size of a hammer, this information emerges from and ultimately serves our lived experience.

What we know and how we understand technology from these primordial experiences thus becomes a topic to talk about. A related issue can be found in the discussions of explanation and understanding in science. Although knowledge acquisition in science and technology cannot be equated, the problem of “scientific understanding” echoes and foreshadows the difficulties of technological understanding.

SCIENTIFIC UNDERSTANDING: A COMPREHENSIVE ACCOUNT OF THE COGNITIVE PROCESS

Not content with merely knowing natural phenomena such as the sun rising in the morning and setting in the dusk; one wants to know why it happens. We call both forms of knowledge scientific: know-that which is descriptive and know-why which is explanatory. Philosophers have been endeavoring to offer definitions and criteria for scientific explanations. A consensus is that, scientific explanations go beyond merely describing phenomena as they intend to answer the why-questions. And in the spirit of logical empiricism: they should not exceed the empirical sphere. Among a series of accounts, the best-known canonical account is the deductive-nomological (DN) model introduced by Carl Hempel and Paul Oppenheim, which serves as the starting-point for contemporary discussions of scientific explanation.

In recent decades, a group of philosophers began discussing scientific understanding. It is not that the term “understanding” never appeared in earlier discussions. Since the beginning, it has been held that scientific explanations foster an understanding of scientific phenomena (for example, Friedman, 1974; Salmon, 1990). That is to say, understanding is the result of scientific explanations. Through correct scientific explanations, we are able to understand how nature works, why the sun rises at dawn and sets at dusk. However, given that scientific knowledge is held to be objective and devoid of any personal quality, explanation’s close association with logical inference places it in alignment with the spirit of science. By contrast, understanding is associated with human, with a psychological and subjective nature. It is widely suspected of lacking epistemic weight and has been overlooked in the philosophy of science.

As of late, the concept “scientific understanding” has attracted increasing attention. The proponents contend that scientific understanding is more than knowledge acquired through scientific explanation. Henk de Regt insists that scientific understanding requires not only knowledge but also the skills of the scientists and the intelligibility of theories (de Regt & Dieks, 2005; de Regt, 2009, 2022). He establishes a model of understanding phenomena, arguing that “pragmatic understanding of theories (UT, intelligibility) is a necessary condition for understanding phenomena (UP)" (de Regt, 2009, pp. 37-38). It is context-dependent, subject-dependent and epistemically relevant. Peter Lipton (2009) highlights the important role of good judgements and tacit knowledge besides theoretical knowledge. Also, he is among those who deny the necessity of scientific explanation for purposes of understanding. He argues that explanation is not necessarily required for understanding, as knowledge may be acquired through other means. In other words, this would be an instance of "understanding without explanation." Johannes Lenhard (2009) exemplifies this by offering an example of computational simulation which empowers scientists to control and predict systems without mastering the theory. Simulation takes the place of theory-based knowledge in its conventional role, giving rise to a phenomenon that may be described as an epistemic black box, and yet it may provide understanding. Meanwhile, there remain philosophers who reject the epistemic status of understanding. J. D. Trout (2002) holds the view that, only explanations and theories that aspire to be true can benefit the development of science, whereas the mere enlightened feeling of understanding something, possibly in light of a false theory or explanation, is subjective and epistemically unrelated. Kareem Khalifa (2012) suggests that the notion of "scientific understanding" solely provides a "repackaging" of explanation in the arguments put forward by proponents.

The central issue that needs to be addressed here is how is explanation and understanding connected? Is "scientific explanation" a necessary and sufficient condition for "scientific understanding," or at least necessary, or neither sufficient nor necessary? If scientific explanation is both necessary and sufficient for scientific understanding, any further consideration of the latter appears superfluous. If there are instances of scientific understanding in the absence of a scientific explanation, then the latter cannot be considered a necessary condition for the former.

I argue that "scientific understanding" deserves careful consideration, yet I would not go so far as to propose that it does not presuppose scientific explanation as a necessary condition. A scientific explanation always introduces a theoretical component. In contemporary scenarios of automation, new computational technologies have come to replace the role of scientists in the process of explanation. It is, however, only the one who explains changes, not the explanation itself disappears in understanding. This de-skilling has long been a trend in scientific and technological development. Analogous to the use of packages in programming, where the underlying principles are enclosed in the package, it can foster the effectivity in research and development. Manipulators do not need to know the mechanism, which facilitates a quicker entry for those from interdisciplinary backgrounds.

However, scientific explanation alone is insufficient to bring about understanding. The two are not equivalent, because a bare theory standing there will not make any contribution, it needs to be grasped by scientific practitioners. An explanation explains a theory successfully only when it is received correctly. "Skills," "judgements," "good sense," and "tacit knowledge" are necessary to the activity of understanding, making sure that explanation can work properly. Gerhard Schurz and Karel Lambert asserts that to understand is to be able to fit a phenomenon into the cognitive corpus of an agent (Schurz & Lambert,1994, pp. 66). If a theory which explains natural phenomena does not fit into our cognitive frame of reference or background knowledge, it has no epistemic value. This is, in fact, a common principle in the field of education: when designing teaching content for children, educators must adapt both the content and its level of complexity to suit their developmental levels and needs. This often involves simplifying the content to ensure it is comprehensible for children.

As with typical application questions that we confront in school, it is generally the case to handle questions in concrete scenario. Patrick Heelan (1998) distinguishes between two layers of meaning when one needs to explain scientifically – a theory-laden meaning and a cultural praxis-laden meaning. These are "merely co-ordinated but not isomorphic." Invoking Heidegger's example of a hammer, Heelan argues that, in order to explain what a hammer is, one must first clarify that it is used for a construction project – this constitutes the cultural and practical part of the meaning of a hammer. In addition, it is necessary to address the theoretical component of the hammer, which includes its specification and functional properties for a construction project. Only the two layers together can make up the whole picture of a hammer. Without knowing the cultural-practical condition, the concept of hammer remains abstract and intangible, making it impossible for us to gain a complete picture of the hammer. The attempt to identify explanations in every new context is already hermeneutical (Heelan & Schulkin, 1998).

The analysis above suggests that "scientific understanding" introduces new issues and questions that call for deeper exploration. Scientific understanding involves a holistic, integrated, and synthetic cognitive practice, it is a form of sense-making, a context-sensitive endeavor. It emerges from at least the co-action of a scientific explanation, the human agent who attempts to understand the natural phenomenon, as well as a certain context, in which understanding takes place and that gives rise to scientific understanding. To explore this human practice, we cannot just focus on a small zoomed-in zone of explanation to thereby neglect the whole picture of understanding.

CALL FOR TECHNOLOGICAL UNDERSTANDING

After the preliminary consideration of technology and the need to achieve understanding of technical artefacts, and after a review of discussions of explanation and understanding in science, we can now venture towards the question of technological understanding.

Technical artefacts and the empirical turn

Our everyday contact with technology is, in most cases, interaction with technical artefacts.[2] Technical artefacts are situated within the category of artefacts, products of

[2] I will not distinguish between "technical" and "technological" in this article, even though one would see more clearly the interrelation between technology and society that is entailed by the term "technological". Since, along with technical products, everything technical interacts with social factors, making this distinction between these two terms would require extra effort and little benefit. For the artefacts designed and manufactured by technological industries, I will use the common term "technical artefacts." With the development of technology, novel forms of technology definitely emerge. This article focuses exclusively on technological products with a material dimension.

technological processes. Conventionally, artefacts are defined as unnatural, mind-dependent, intentionally made objects for realizing particular purpose (Hilpinen, 1992; Baker, 2004; Preston, 2022).

Analogous to the differing views of science and technology, we can also observe contrasting attitudes toward natural substances and artefacts. This can be traced back to ancient Greece. In his *Nicomachean Ethics*, Aristotle distinguishes between natural and artificial objects in terms of the "first principle," and this distinction is accompanied by a clearly articulated hierarchy. While natural substances are considered to be "things that are or come into being by necessity," their existence does not rely on human will, "they have their first principle within themselves." Technical products, on the other hand, don't have their "first principle," they are human-made, mind-dependent, and it is the producer who brings them into being (Aristotle, 2000, p. 106). In this sense, artefacts are inferior to natural substances which exist necessarily in the world. The marginalization of artefacts has resulted in the prolonged absence of artefact and materiality in metaphysics. Some philosophers even claim that "artifacts such as ships, houses, hammers, and so forth, do not really exist" (Hoffman & Rosenkrantz, 1997, quoted in Baker, 2007). Till now, the ontology of artefacts remains a challenging question.

Technology and technical artefacts have finally reached a turning point in terms of their recognition, due in large part to the empirical turn in philosophy of technology. A group of philosophers began to focus on the material dimension of technologies. According to Philip Brey (2010), the empirical turn comprises two different approaches: the society-oriented and the engineering-oriented approach. The society-oriented approach seeks to analyze the influence of technologies on humans and society. As one of the most representative philosophers, Ihde (1990; 2009) is known for his contribution of technologically mediated perception and material hermeneutics. Other notable figures include Bruno Latour, Donna Haraway, and Peter-Paul Verbeek. On the other side, the engineering-oriented approach focuses on the technological practice and systems or devices themselves rather than their impact. Carl Mitcham (1994) is considered among the earliest scholars to call for a refocus on technology itself. He advocates active dialogues between philosophers of technology and engineers. Heeding his call is a group of philosophers including Joseph Pitt, Peter Kroes, Anthonie Meijers, Pieter Vermaas, and Wybo Houkes.

Despite taking different directions, they nonetheless share common ground and can benefit from each other to some extent. Unlike classical philosophy of technology, both approaches no longer restrict the focus on metaphysical and transcendental conditions of technology. Technology is treated not only as an unreducible abstract notion. Rather, analyses are concrete and empirical, turning to more specific and detailed modern technologies and focusing on human experience. Another notable commonality lies in the fact that both approaches emphasize description rather than evaluation. Philosophical reflection of technology "should be based on empirically adequate descriptions of technological practices and technical artefacts" (Meijers, 2000, p. 93). The trend turns from the classical normative and evaluative philosophies of technology towards empirical and descriptive ones (Brey, 2010; Franssen et al., 2016).

Discussions on technological explanation

“Technical artefacts” are of central concern to the engineering-oriented philosophers. Kroes and Meijer’s proposal regarding “the dual nature of technical artefacts” created a new framework for research (Kroes, 1998; 2006; 2010; Kroes & Meijers, 2006). They define technological artefacts as “(i) designed physical structures, which realize (ii) functions, which refer to human intentionality” (Kroes & Meijers, 2006, p. 2). In this sense, technical artefacts have on the one hand physical structures that allow them to realize their function, on the other hand, they are intentionally created to realize a certain function, they are inscribed with a “for-ness”, i.e. a teleological element. Both are indispensable; neither the physical structure nor intentions alone are sufficient to constitute a technical artefact. And yet it does not provide an ontology of technical artefacts. The theory of dual nature does not deliver an account of the essences of technical artefacts is (Houkes et al., 2011). Instead, it offers conceptualizations from two different perspectives from which we can read artefacts in terms of the tension between designing and using.

Following this direction, we will soon confront two familiar philosophical themes. Since technical artefacts have two conceptualizations from physical and intentional perspectives, how are these related? It is in fact a mind-body problem (Kroes & Meijer, 2006). The notion of “function” seems well-suited to bridge the two poles, since from one perspective the designed physical structures are to realize functions, and functions, from the other perspective, refer to human intentionality. In order to bridge the gap, Vermaas and Houkes with their research group introduced the ICE-theory on technical functions and analyzed the “use plans” in different cases of designing and using (Houkes et al., 2002; Vermaas & Houkes, 2006). By incorporating the notion of function, one finally arrives at a tripartite model of the conception of a technical artefact. It involves a physical structure, a technical function, and a context of intentional human action (Kroes, 2010).

Even prior to the emergence of the dual nature project, Kroes (1998) had introduced a pair of terms – technological explanation and functional explanation – in portraying the relation between structure and function of technical artefacts. [3] While functional explanation is invoked where function explains structure, a technological explanation serves to explain how a physical structure can realize the function:

> A design also contains (at least implicitly) an explanation of how the proposed physical system will be able to perform the required function. In other words, a design also consists of a technological explanation, i.e., an explanation of the function of a technological object in terms of the physical structure of that object. A technological explanation is an integral part of a design and plays a crucial role in justifying a design: it shows that on the basis of its physical structure an object will perform a certain function. (Kroes, 1998, p. 125)

[3] Kroes used the term “technological objects” in an early paper on “Technological explanations: the relation between structure and function of technological objects”, whereas “technical artefacts” in later writings. Since there is no obvious difference between them, I will use “technical artefacts” to indicate both terms in Kroes’s writings to ensure terminological consistency across this paper.

Kroes also differentiates technological explanation from physical explanation: Whereas the former explains the function of an artefact, the latter explains how the structural composition will result in a physical movement.

From daily activities, it is plausible that the physical structure and the function of a technical artefact are closely related. Function is realized through a specific physical structure. This relationship distinguishes technical artefacts from social objects whose function is based on collective intentionality (Kroes, 2010). However, a logical gap exists between structural and functional descriptions. As different structures can realize the same function, and a structure can conversely realize multiple functions, the inference does not work in both directions. A technological explanation is thus not a deductive explanation, it cannot be fitted into the DN-model. Kroes also points out that the "for-ness" of a technical artefact involves a normative dimension. In this sense, the coherence between functional and structural descriptions turns out to be an is-ought problem: how a technical artefact ought to function cannot be derived from what the structure is. Addressing this question requires more than purely deductive relations. Given that technical function is action-oriented, practical reasoning needs to be inclusive in order to bring the perspective of intentionality into consideration (Kroes, 2006). A similar observation has been made by philosophers from the society-oriented approach. It aligns with what Ihde(1990) calls the "ambiguity of technology".

Jeroen de Ridder (2007) criticizes Kroes for attempting to explain the function of technical artifacts solely through the analysis of the physicochemical structure. The reason is that the function and physical structure of an artefact are actually not directly connected. His proposal is a combination of two independent but related theories – a function theory which "explicates the conditions under which an intended behavior is the artifact's function" and an artifact explanation which "explains how the artifact is able, in virtue of its physicochemical structure, to show this behavior" (de Ridder, 2007, p. 215). He explicitly points out that the function of a technical artefact cannot be considered in isolation without context such as its ecological niche, its history, designers, users, as well as their intentions and beliefs.

Joseph Pitt insists on the priority of epistemological issues, claiming that we cannot conduct fair and reliable assessments regarding the impact of technology unless we understand "how we know that what we know is reliable" (Pitt, 2000, p. viii). Compared to scientific explanation, Pitt attributes a greater number of tasks to technological explanation: to explain what makes a technical artefact what it is, to explain its role in society, to explain technological failures and attribute responsibility (Pitt, 2009). The search for universality in scientific explanation cannot be meaningfully applied to technological explanation, as what is mainly at stake in technological explanation are the human-made technical artefacts. An artefact-specific explanation is not satisfying and exhaustive. Since no single aspect of an artefact can be explained in an isolated sense, he argues that all the factors in a technological explanation require an appeal to systems, which is essential to being able to offer or understand a technological explanation. For example, sometimes a deeper insight into the electric grid and even historical factors will be needed to answer the question "Why did that light bulb turn on?" In addition, the answer will vary depending on the interest and purpose of the question – who raises it and why – and on how much depth and detail is expected by the audience. Someone may only expect an answer like “Because the switch was flipped.” One needs to identify in these instances exactly what the question is, adjusting the answer accordingly (Pitt, 2009).

The various authors who join in these efforts agree that deductive reasoning is insufficient for a satisfying explanation of technical function because a deductive reasoning does not move smoothly between two poles. A technological explanation should go beyond a pure deduction and must involve something practical and social. Notably, Pitt expands the scope of technological explanation beyond its definition and differentiation by Kroes. For Kroes, a technological explanation is intended to explain and justify the design of a technical artefact. Even though it seems to require practical reasoning, the goal remains restricted to an argument about the technical artefact itself. In the contrast, Pitt takes into consideration the context of explanation. He attaches more importance to the question of what and how an audience wants to understand a technical artefact.

Necessity of technological understanding and a hermeneutics of technology

I would argue that what Pitt seeks to do goes beyond a theory of technological explanation and touches on that of technological understanding. What I call for is a philosophical exploration of technological understanding. In order not to get confused, we need to distinguish these two notions before further investigation.

Coming from the widely recognized difference between explanation and understanding, as discussed in previous sections, I would borrow the definition of technological explanation from Kroes and make a small revision. A technological explanation is an explanation of the possibility of potential functions that a technical artefact can realize, based on the physical structure and presupposed usage scenario. In many cases, it is not a fixed answer. It is more than an artefact explanation as proposed by de Ridder which is dedicated to offer information about what this structure can provide and why estimated functions can be realized. This explanation is not a deduction, but synthetic reasoning for engineering design. It can function as a justification of design, and also act as a theoretical foundation and guideline for engineering design.

By technological understanding, I refer to the way in which we make sense of our interactions with technical artefacts. A philosophical reflection on technological understanding concerns the conditions for this sense-making. It is a holistic and synthetic investigation of how we learn to know technology, taking into consideration the context and human agents who interact with the technical artefacts. This does not differ much from what Pitt advocates for within the notion of “technological explanation.” In this regard, an analysis of technological understanding provides the insight from a user's perspective, which can play a supportive role in technology assessment and the improvement of engineering design.

Whereas scientific understanding usually occurs in specific academic contexts, technological understanding occurs more frequently. It takes place not only among engineering designers in academic fields, but in our mundane daily life; not only when we encounter a new product, but all the time we interact with technical artefacts. We perceive, understand, and use the technical artefacts based on specific conditions in every interaction. Even tools that are ubiquitous in everyday life can take on new purposes when situated in a different context. The meaning of a technical artefact may vary from person to person, from time to time, from scenario to scenario. This unfixed, situated and context-sensitive characteristic of technological understanding highlights why it is difficult to deal with the ontological issues of technical artefacts.

Scientific understanding is attributed to a confluence of human agent, theoretical scientific explanation, and the specific context, although the function of scientific explanation is sometimes carried out by computational technologies instead of scientists. What is the analogous situation in the case of technological understanding? As previously stated, technology is a primordial way of knowing. For most lay people, when we interact with technical artefacts without instructions, we rarely mathematize and theorize them, instead, we perceive and manipulate them directly. I intend to borrow the term "affordance" to describe what technical artefacts provide human agents. "Affordance" is a concept introduced by James Gibson in ecological psychology, referring to what the environment can offer and furnish (Gibson, 1979). This notion emphasizes a direct perception, it is primitive sense-making. For example, a flat platform affords support, a handle affords to be gripped. Later, this concept is borrowed by Madeleine Akrich, Bruno Latour and Don Norman conversely for design process (Akrich & Latour, 1992; Latour, 1994; Norman, 2013). They all express the similar standpoint that "affordance" needs to be embedded in design so as to guide users to use the product according to what is supposed. Taking a wider view, it can be seen that understanding must take place somewhere, a context where the artefact is used, where the understanding occurs. As Ihde has observed, technology is always only what it is in some cultural and use context, thus giving rise to the "ambiguity of technology." And even in an identified context, the same artefact can be understood differently by different users, highlighting the role of the human agent in understanding. This aspect encompasses skills, aesthetics, creativity etc. which may be very personal. The above is merely a preliminary and incomplete attempt at exploring the factors in the understanding of technology. Yet it is evident that the affordances of a technical artefact, context and human agency play key roles for technological understanding.

Once we are talking about understanding, meaning, and sense-making, we have turned to the field of hermeneutics. The initial, primitive, context-sensitive, always re-interpreted, historically-situated meaning is the core issue in hermeneutics. To some extent it may share its main concern with epistemology, however, it does not seek to reveal the inner structure of cognition as conventional epistemology does, but to shed a light on the condition prior to the theoretical thematization and transformation from our fuzzy lifeworld to mathematized abstract world. Before we start to grasp their structures and build up an abstract theoretical model of them, we have already formed primitive, pre-theoretical knowledge. Hermeneutics can complement what epistemology cannot provide and thus bridges two worlds (Ginev, 1995). Ihde (1990) introduces the notion of "cultural hermeneutics" to demonstrate the cultural embeddedness of technology and to highlight the importance of examining concrete cultural contexts when evaluating technology. Recognizing a set of common foundations, considering technological understanding and hermeneutics of technology may jointly offer valuable insights.

CONCLUSIONS AND PERSPECTIVES

To sum up, I call for more attention to technological understanding and this paper set out to explore how the discussions on scientific understanding can be projected onto technology. By an inquiry from historical and ontological perspectives, it can be reasonably claimed that technology is a more primordial way of knowing than science. However, there is a lack of relevant discussions due to prolonged neglect of technology and materiality in philosophy. Thus, similar discussions of scientific explanation and understanding in philosophy of science can serve as a guidance. A brief examination reveals that adequate scientific explanation does not guarantee the acquisition of all knowledge. Only a confluence of a scientific explanation, human agency and social context can give rise to scientific understanding. The investigation of “scientific understanding” deserves careful consideration. But back to technology, the research topic of technological explanation is already situated among the core concerns in philosophy of technology after the empirical turn. Kroes (1998) defines it as “an explanation of the function of a technological object in terms of the physical structure of that object” (p. 125). A consensus shared among philosophers who have explored this question is that deductive reasoning is insufficient for producing a comprehensive explanation of function in terms of physical structure because of the multistabilities of the physical structure as well as function of a technical artefact.

To obtain a holistic view of how we understand technology, I introduce the notion “technological understanding.” It refers to the way in which we make sense of how to interact with a technical artefact. A philosophical reflection on technological understanding is thus a comprehensive investigation into how we come to know a technical artefact with respect to the conditions for sense-making, benefitting technology assessment and providing insight for designers. Furthermore, the acknowledgement of and concern with sense-making of situated, context-sensitive meanings lie within the scope of hermeneutic traditions. Accordingly, hermeneutics can be employed as a productive lens for exploring technological understanding.

The task ahead is to undertake a deeper exploration of the factors within technological understanding in conjunction with hermeneutics. For example, what still remains untouched here is the dimension of art. Given that both technical artefacts and artworks are human creations, can our discussion on technological understanding gain any insight from the hermeneutics of artworks as well?

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