Published in: Building Bridges. Connecting Science, Technology an d Philosophy. Eds.: H. de Regt and C. Kwa, VU University Press, Amsterdam, 2014. pp. 175-187.

On the science-technology relationship: a historical view

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Several years ago I was fortunate to talk with a well-known philosopher of technology about the science-technology relationship. He had a categorical view on the matter: "It is simple. Science deals with facts, and technology deals with artefacts." His conceptualization was really attractive (and I realized it was of Aristotelian origin),[1] and yet as a philosopher I was not completely satisfied. How can we uphold this view, given that facts and artefacts are really difficult—if not impossible—to tell apart? On a constructivist account, for instance, facts and artefacts seem to be indistinguishable. He responded, smiling: "You should not be a constructivist then!"

But I am a constructivist—or at least I highly appreciate many constructivist ideas. Having been trained in physics and in philosophy, my background was in fact quite similar to that of Hans Radder. "To be frank, I should say that—from an autobiographic point of view—I find all [this] empiricist metatalk rather embarrassing. I started my philosophical studies at the time of the decline of the logical empiricist tradition. I then welcomed the subsequent postpositivist and constructivist approaches."[2]

In this context, I did not find the "simple" conceptualization of the science-technology relationship offered by my prominent interlocutor satisfying at all.

1 A clear distinction between *natural* things ("that […] exist by nature") and other—*artificial*—things ("which are not constituted by nature") is a key issue in the Aristotelian philosophy of nature. See e.g. Aristotle, *The Physics with an English Translation*, trans. P.H. Wicksteed and F.M. Cornford, I–II. vols. (Cambridge: Harvard University Press, and London: Heinemann, 1957), 192b8, vol. I. 107.

2 Hans Radder, *In and About the World. Philosophical Studies of Science and Technology*, (Albany: State University of New York Press, 1996), 172. Perhaps an autobiographic note is in order here. Hans and I had not only the intellectual environment in common but many other aspects of our life as well. Our similar living and cultural contexts made it possible for us to form a kind of intellectual "peerness" and a personal friendship in the last two-three decades, which is a continuous source of pleasure for me. The ideas developed in this paper I dedicate to Hans.

It is clear that the problem of the science-technology relationship cannot be solved on an empirical basis only. An appropriate *philosophical* position is needed instead.[3] At the second glance, however, it seems to be also obvious that all the factors that need to be considered here, as well as their interrelationships, have undergone significant *historical* changes, and therefore, the science-technology relationship cannot be properly analyzed without reflecting on the history of science, on the history of technology, on the history of philosophy, or on cultural history at least. Unfortunately, in current scholarship there are hardly any common historical analyses of these issues, apart from some studies on technoscience which emerged over the last two decades.[4]

In this paper I shall take into account both philosophical *and* historical arguments so as to develop a conceptualization of the science-technology relationship. Not surprisingly, I will arrive at an (historically informed) concept of technoscience.

It is perhaps surprising that I should base my argument about the nature of the science-technology relationship on human history and/or cultural history rather than on the history of various scientific disciplines. I propose that in order to understand the relationship between science, technology, and philosophy, it suffices to consider the sequence in which they emerged in the course of human history; other aspects of the history of these various cultural entities are of secondary importance.

The birth of science and the birth of philosophy are well-known and frequently discussed topics. But the situation changes radically when it comes to technology. On the one hand, it is not easy to study the early forms of technologies;[5] on the other hand, unlike in the case of early philosophy and science, there is no consensus

3 Radder, *In and About the World*, 169–187; Hans Radder, "Science, Technology, and the Science-Technology Relationship" in *Philosophy of Technology and Engineering Sciences*, ed. A.W.M. Meijers (Amsterdam: Elsevier, 2009), 65–91; and Hans Radder, *The Material Realization of Science. From Habermas to Experimentation and Referential Realism*, (Dordrecht: Heidelberg: New York: London: Springer, 2012), 161–190.

4 See e.g. the papers in the volume 13, nos. 2. and 3 of *Perspectives on Science*, especially Barry Barnes, "Elusive Memories of Technoscience," *Perspectives on Science* 13 (2005): 142–165; Ursula Klein, "Technoscience avant la lettre," *Perspectives on Science* 13 (2005): 226–266; John Pickstone, "On Knowing, Acting, and the Location of Technoscience: A Response to Barry Barnes," *Perspectives on Science* 13 (2005): 267–278. See moreover John Pickstone, *Ways of Knowing. A New History of Science, Technology and Medicine* (Chicago: The University of Chicago Press, 2001).

5 See e.g. the problem of papyrophobic technology vs. papyrocentric science in Derek J. de Solla Price, "The Parallel Structures of Science and Technology," in *Science in Context. Readings in the Sociology of Science*, eds. Barry Barnes and David Edge (Milton Keynes: The Open University Press, 1982), 164–176.

among historians as to what constitutes technology, i.e. how to define technology in a way that will help identify and interpret it in all stages of its development, from primitive forms to modern versions. In other words, identifying the birth of technology involves philosophical problems, and these problems are intertwined with the problem of defining technology. In this essay, I shall propose a novel concept of technology, one that encompasses all forms of technology, from the most primitive human practices to Internet usage, from the beginning of human history to the present.

The central claims of the paper—all of which are based on considerations regarding the historical emergence and development of technology, science, and philosophy—may be formulated as follows:

> *Thesis one* asserts the primacy of technology. This is based on the fact that the emergence of technology in human history preceded the emergence of philosophy and of science.
> *Thesis two* claims that there is no science without philosophy. Historically, (European) philosophy emerged several hundred years before science did; science does not exist without (or prior to) philosophy.
> *Thesis three* proposes that science equals to technology plus philosophy. This implies that the coexistence of technology and philosophy is prerequisite for the emergence of science.

Technology as an aspect of human praxis

So as to meet the objective of this paper, which is to arrive at a conceptualization of the science-technology relationship in general, a rather special concept of technology is needed. In particular, the concept of technology must be broad enough to include technology in all its historical forms, primitive tool-making as well as recent information technologies. No doubt this is an "essentialist" or "substantivist" view on technology,[6] since only an essentialist view is capable of accounting for the features that protean historical forms of technology have in common, and hence of

6 See e.g. Andrew Feenberg, *Questioning Technology* (London: Routledge, 1999); Hans Radder, "Critical Philosophy of Technology: The Basic Issues", *Social Epistemology* 22 (2008): 51–70; Andreas Beinsteiner, "Das Wesen der Technik: Relating Heidegger's Philosophy of Technology to Media Studies" (paper presented at the Hermeneutics of Science and Technology—A Reconsideration. 20th Anniversary Conference of the ISHS, Vienna, Austria—Budapest, Hungary, July 28–August 3, 2013).

identifying the point in time when technology was born. However, instead of following in Heidegger's or Ellul's footsteps, I propose a different philosophy of technology based on a more universal concept of technology.[7]

I propose that the essence of *technology is a specific form or aspect of human agency, the realization of the human control over a technological situation*. In consequence of the deployment of this human agency, the course and the outcome of the situation are no longer governed by natural constraints but by specific human goals. The human control of technological situations yields artificial beings as outcomes. Since technological situations vary and they are not homogeneous in nature, they can be identified on the basis of their constituents. The components that make up a technological situation are a set of (natural or artificial) beings, humans (or human agencies), their aims, and (situation-bound) tools. In Hegel's words, the essence of technology necessarily appears in concrete, particular technologies only, while on the other hand, all technologies necessarily embody the essence of technology.

According to this view, every element of the human world is created with the help of technologies. Both human nature and social being are the products of our technological activity, and their characteristics are determined by the specificities of the technologies we use to produce them.

In comparison with widely accepted views on technology, this view implies an extremely general and abstract conceptualization of technological praxis. In particular, all human praxis appears as technological, or better said, as having a technological aspect or dimension. The view on technology proposed above is therefore really close to a philosophy or theory of human actions. Human practice consists of the—imperfect—realization of human control over a situation. Human practice is of course not identical with technological praxis, as the former has several other aspects as well, but it always and necessarily has a technological aspect too. Moreover, every human situation can be regarded as a technological situation, every human being as a technological agent, every human goal as accomplishable by a specific technology, and every human tool as a situation-bound technological tool. The technological aspect of human practice is a response to human vulnerability and expresses the intention to gain control over the situations of our lives. Without such an—evidently partial—

7 More details can be found in my Hungarian book: László Ropolyi, *Az Internet természete. Internetfilozófiai értekezés (On the nature of the Internet. A discourse on the philosophy of the Internet)* (Budapest: Typotex, 2006), 41–72. A draft version of its English translation is available online: László Ropolyi, "Philosophy of the Internet. A Discourse on the Nature of the Internet," last modified December 18, 2013, http://elte.prompt.hu/sites/default/files/tananyagok/philosophy_of_internet/index.html

success we would cease to be human beings; we would take part in natural situations as natural—animal—beings. For this reason, every technology is a technology of humanity: the human beings, the human world, cultures and societies are all products of technologies. Further, technology is the only way humans can create themselves. Technology was born together with human beings. Various branches of technology can be associated with various types of life situations. Our self-creating praxis is facilitated by a range of economic, legal, psychic, social, cultural, material, mechanical, etc. technologies.

In my view, engineering is a meta-technological activity, a specific practice of handling the components of technological situations, which aims to set up controllable situations in a given, complex, infinitely extending environment.

In spite of some fundamental differences with respect to goals, vocabulary, philosophical background, crucial components, and complexity of elaboration, the above described view on technology and Radder's theory of technology[8] have much in common. Radder describes technology as a "(type of) artefactual, functional system with a certain degree of stability and reproducibility" and in a subtle analysis he considers "the question of how we may successfully realize and maintain such technologies, which […] reveal a number of equally important characteristics of technologies."[9] Both views accord a crucial role to "human intervention" on a set of beings surrounded with an environment, with intervention resulting in material and symbolic artefacts, etc. Although Radder's analysis is interesting, significant, and highly complex, it is hard to see how it may help elucidate the nature of the technology-science relationship. It is perhaps no accident that in his paper on the science-technology relationship, Radder does not refer to his own theory of technology.[10] The view proposed here is hopefully more useful for this purpose.

Given the above conceptualization of technology, it is evident that technology has primacy over intellectual practices such as doing philosophy or doing science. This is because being a human is prerequisite for being a philosopher or for being a scientist. Evidently, there is no philosophy or science without specific, historically determined technological practices. In other words: philosophy and science (as well as any other field of human culture) necessarily rely on and thus include technological components.

This view, combined with Feenberg's comparative analysis of the philosophies of technology[11] yields the insight that technology is not autonomous from humans

8 Radder, "Critical Philosophy of Technology."
9 Radder "Critical Philosophy of Technology," 52.
10 Radder, "Science, Technology, and the Science-Technology Relationship."
11 Feenberg, *Questioning Technology*, 9.

or from society, and it is not value-free either. It is embedded, practically and culturally, in the social system and in the human life-world—and we may hope for a Habermasian synthesis of these two context-dependencies.

The technology-science-philosophy relationship

One consequence of the above proposed philosophy of technology is the following thesis: *science equals to technology plus philosophy*.

The 'science = technology + philosophy' formula is not my invention, although I am unable to identify its originator. I stumbled across it in a message sent as a contribution to an online discussion on a discussion list.[12] As far as I can remember, the author of this contribution wrote: "as everybody knows, science = technology + philosophy". The statement came as a complete surprise to me, and this in spite of my long practice in doing and teaching philosophy of science. As I realized later, my astonishment was due to the fact that philosophical reflection on science, technology, and philosophy are usually performed in isolation, published in different journals by different scholars working in different intellectual traditions and often in different disciplines, without any serious consideration of the scholarship produced in the other two fields. In consequence, the philosophy of science, the philosophy of technology, and philosophy proper have effectively become separate fields under the sway of the positivist meta-methodology of intellectual activity. Accepting this methodology makes it nearly impossible to consider these fields in relation to each other, or even to conceive of the possibility of their interrelatedness.

As I began to reflect on these problems, I gradually became aware of my own intellectual situation. I recalled my earlier impression that the positivist methodologies had lost their lure, giving way to alternative methodologies such as various post-positivist trends in the philosophy of science, hermeneutic and constructivist views of science and technology, the postmodern condition, and so on. I realized that this ideological rearrangement resulted in these newer approaches to science and technology being cultivated under the names of sociology of knowledge, social constructivism, social epistemology, and hermeneutics of science and technology, while in a parallel move, the traditional domains of reality, their borders, and the borders separating the scientific disciplines which study them were reinterpreted. I also discovered a newly

12 Unfortunately, I cannot remember the names of the discussants or the topic. I surmise that the discussion took place in 1999 on the *HOPOS-L*, *technology*, *sts*, or the *philosop* list or on some other such list. I could not however locate the statement in my archives of the aforementioned lists.

established approach called *technoscience*, where science and technology are regarded to be almost inseparable from each other, with their most important characteristics being part of the same ontological and epistemological universe. The prevalent view in postmodern *cultural studies* is that science and technology are integral and hardly separable components of the culture of an age; their content significantly overlaps with that of other cultural domains and entities, including social interests and values, philosophies, religions, art, or even popular culture.

Under these intellectual conditions, it is only natural to reflect on the interrelationships between science, technology, and philosophy; moreover, such an inquiry seems to be extremely important and fruitful. Following this insight, I started to study these exciting problems and found it necessary to consider some fundamental aspects of the 'science = technology + philosophy' thesis and what it implies for the analysis of science, technology, and philosophy.

The thesis is a formal statement of the interrelatedness of science, technology, and philosophy, which requires some interpretation. A "strong" interpretation emerges if the components of the thesis are represented on a Venn diagram: science then appears as the intersection of technology and philosophy. This reveals two important aspects of the science-technology-philosophy relationship: first, that only some, and not all, elements of technology and philosophy are incorporated into science; and second, that science is essentially heterogeneous, containing both technological and philosophical components. The "weaker" interpretation highlights the second claim: everything scientific includes something technological and something philosophical. In the remainder of this paper, I shall confine myself to this weaker interpretation.

By rearranging the formula, we may obtain further versions of the thesis, each of which sheds light on and emphasizes different aspects of the science-technology-philosophy relationship. The classical version (science = technology + philosophy) gives us insight into the nature of science. The formula 'science—technology = philosophy' (science minus technology equals to philosophy) discloses the ideological role played by science and calls attention to the fact that philosophical principles are constitutive of science. The formula 'science—philosophy = technology' (science minus philosophy equals to technology) is useful for the understanding of the so-called "technicization" of the sciences, as well as for the conceptualization of what is called "applied" science. Just as the three versions of the formula are helpful in understanding various aspects of science, they might just as well be used as points of departure for similar analyses of philosophy or of technology. Folding out all these implications is clearly beyond the scope of this paper, so I shall continue to focus on the "classical" formula and on what it implies for science.

Historical considerations concerning the sequence of the emergence of science, technology, and philosophy constitute an historical argument for the 'science = philosophy + technology' thesis. Technologies are the oldest components of culture, while philosophy and science emerged in a relatively late period of the human history. On the other hand, science emerged a few hundred years after philosophy. There were no sciences without and prior to effective technologies and existing philosophies.

Earlier in the paper, I claimed that this sequence of emergence of the respective cultural entities establish *the primacy of technology* over science and philosophy. I argued that the validity of the primacy of technology thesis is rooted in human beings' need to control their living environment for the sake of survival. The essence of technology is the effective control of a situation. Making and using tools serve this goal. Since any tool is a tool in a given situation only, tool-making requires some interpretation on the part of the tool-maker. Tool-making is therefore a kind of hermenutical praxis, the creation of artifacts based on the situation-bound (re)interpretation of natural beings. Every version of technology, from primitive human techniques to present-day computer technology, gains control over a technological situation with the help of situation-bound knowledge the scope of which normally does not extend beyond the particular situation at hand.

There is one more historical argument concerning the emergence of philosophy in the ancient time. It is well-known that the birth of philosophy preceded the birth of science in Ancient Greece, as well as in every other parts of the world. The second thesis of this paper expressed this relationship saying that there is no science without philosophy.

Philosophy is completely different from technology. Since its inception, the *usefulness of philosophy* has been frequently debated. Philosophy is not very useful in controlling situations; as a source of uncertainty, it may even impede the achievement of this goal. The aim of philosophy is to explore situations, not to control them. It aims at disclosing the ultimate truths. Making and using concepts serve this goal. The essential practices of conceptual thinking are questioning, reflecting, and critical thinking. A prerequsitie for these activities is the recognition of the lack of certainty, which makes the production of philosophical ideas an endless process. Further, the scope of validity of a philosophical idea is the entire world: philosophy seeks to understand how and why the world became the way it is. In short, every version of philosophy constructs worlds with the help of universal (not situation-bound) knowledge.

Science accepts, includes, uses, combines, cultivates and improves numerous aspects of the controversial natures of technology and philosophy. In comparison with technology, science is useless for practical purposes and is thus inferior; in comparison with philosophy, it is limited, restricted, and praxis-bound. Science

includes both situation-bound experiences *and* universal principles and laws. It does not build or control real-life situations, but rather discovers and creates conceptual systems. Because it is oriented towards survival or effectiveness, technology is focused on the present (*hic et nunc*) instead of the past and the future. Whereas survival is something that poses tasks to be solved "here and now", critical thinking and reflexivity have space-time needs. Therefore, technology is finite while philosophy is infinite; if technology is punctuated, then philosophy is a line, and science is a segment. Philosophy constructs worlds for science using technological situations as building blocks. Scientific knowledge is about knowing how, knowing what and knowing why.

In short, the human control over technological situations and the creation and use of tools, i.e. any technological praxis is *situation-bound*. But the characteristics of science are very different—the opposite in fact: science aims at *situation-independent* (universal) knowledge, one that is valid across a range of situations (optimally in all situations). This invites the question how is it possible to construct universal claims on the basis of a technological praxis every element of which is necessarily situation-bound. The answer is this: with the help of philosophical principles and ideas. Philosophy is capable of creating worlds out of situations. Consequently, the combination of certain elements of technological *and* philosophical praxis results in scientific praxis.

In philosophy, there are many different ways of world-making. Perhaps the most popular one is the *Platonic* way, i.e. world-making by "justification". Plato defines knowledge as justified true belief/opinion (*doxa*), providing a clear connection and a distinction between belief and knowledge. The *Aristotelian* way of world-making (world-making by "inquiry for causes") is better suited for our purposes. For Aristotle, knowledge is the knowledge of causes. Aristotle makes a connection and distinction between knowing (being acquainted with something) and knowledge. Knowing means knowing the contingent, whereas knowledge is knowing the necessary. Another distinction made by Aristotle is that between *epistêmê* and *technê*, i.e. knowledge of things created by nature vs. knowledge of things created by craftsman, or, in other words: the knowledge of natural vs. artificial beings.[13]

We may use the above mentioned Aristotelian ideas and principles to make a clear connection and distinction between technology and science. Technology is a human praxis based on an ability called "*technê*" (knowing, a situation-bound art of creation) by the ancients, which is effective in concrete situations, and which

13 See e. g. Richard Parry, "Episteme and Techne", In *The Stanford Encyclopedia of Philosophy* (Fall 2008 Edition), ed. Edward N. Zalta, last modified Oct 28, 2007. http://plato.stanford.edu/archives/fall2008/entries/episteme-techne/

Table 1. A comparison of science and technology

Science	**Technology**
Beings "given by nature"	Artificial beings
"Epistêmê"	"Technê"
Knowing the necessary (knowledge)	Knowing the contingent
To know why	To know how
Abstract and universal laws	Concrete and particular rules
Situation-independent truth	Situation-bound validity
Eternal and global	Temporal and local
Unified	Plural
Contemplative	Reasonable
Focus on reality	Focus on potentiality
Truth	Effectiveness
"Dezanthropomorphic"	"Anthropomorphic"
Created by a "philosopher"	Created by a "craftsman"

aims at knowing contingent relationships. Exploiting its effective control, technology sustains artificial situations and creates artificial beings including cultures, social structures, personalities, artifacts, etc. Science is a different human praxis based on an ability called "*epistêmê*" (knowledge, a situation-independent art of consideration), knowledge which is valid in every situation, and which aims at discovering necessary (e.g. causal) relationships. Enjoying its contemplative freedom, science compares as many concrete situations as are available. It studies the world of given (by nature, culture, society, etc.) beings, and creates necessarily interrelated conceptual systems to describe and explain reality, including nature, culture, social and mental structures, etc. Due to the ontological and historical primacy of technology to science, the origin and the toolkit of the former appears as "natural". It is however unclear where science comes from, how it could separate from technology, how it was able to make the breakthrough from contingency to necessity, and so on. The answer, in short, is that all of these changes were the outcome of interactions between ancient technology and ancient philosophy. In a few hundred years, the results of these interactions stabilized, giving rise to a new cultural entity: science. Since then, the organizing principles and the most fundamental characteristics of this entity have remained the same, and we can summarize them in the form of the equation 'science = technology + philosophy'.

There is no room here for further arguments; however, the history of technology and the history of the formation of various scientific disciplines provide ample illustration for the validity of this conclusion. Table 1 presents and contrasts further characteristics of science and technology.

If technology and science differ, or are even the opposites of each other in so many respects, then how come they are interconnected? How is the relationship between them established? The answer is: it is *philosophy* that *connects the two sides*, or, more precisely: philosophical generalizations transform the technological characteristics into scientific ones. Different philosophies construct different sciences out of the same set of technological situations. Historical, social, and personal variants of scientific disciplines, practices, methodologies, ideas, interpretations, etc. are the results of the application of different philosophical ideas and principles to the case at hand. Identifying the philosophical content—and its origin—underlying these variants is the business of the philosophy of science. I now would like to mention a few illustrations for this claim.

The crucial methodological problem is how we can create a world (for science) from the separate situations (of technology)? According to a naive, but popular philosophical world-construction, the world is a simple collection of situations, i.e.

$$\text{world} = \text{situation}(1) + \text{situation}(2) + \ldots + \text{situation}(n),$$

where n is finite or infinite, depending on philosophical preferences. Needless to say, there are many more sophisticated world-making methodologies in philosophy, but this simple version will do for my purposes, which is to demonstrate the double nature of scientific experimentation. When doing science, scientists try to create new situations (these are sometimes called experimental situations) so as to test scientific claims. In this way, the goals of experimentation are scientific (situation-independent), but their means are technological (situation-bound).[14]

Based on the thesis, the relation between the concepts of scientific models and theories can be easily described: 'model + philosophy = theory'. That is to say, a scientific theory is a situation-independent model created via philosophically motivated interpretation.

The relation of knowledge and power has been always an important question for every age. On the account proposed here, the Baconian idea "knowledge is power" has a very specific meaning, namely, that in the modern era science has a highly technological and hierarchical character. In general, technology is acquainted with power, while science is not, being a contemplative and democratic practice (where democracy refers to the democracy of situations in the first place). Problems like this play an important role in the modern-postmodern transition and in its descriptions by Heidegger, Habermas, Lyotard and others.

14 I think these ideas are in line with Hans Radder's thoroughgoing analysis of scientific experimentation presented in *The Material Realization of Science*.

Beside the usual (subject-level) reflection on science (i.e., on the subject-field of the discipline in question), we may also reflect on scientific activity itself (i.e., on the methodological problems of the sciences). This meta-level reflection addresses questions like: what is the technology of making good science? Differentiating this meta-level analysis, we may speak about meta-technology, meta-philosophy and meta-science, and address the question of their interrelatedness just as we did on the subject level. Recent trends in the philosophy of science and technology, techno-science, science studies, etc. combine the elements of meta-technology, meta-science and meta-philosophy in various ways—often without reflecting on the activity of doing the combination. (In principle, there are an infinite number of meta-levels, but in (philosophical) practice, not all of them are attended to). Many debates in the philosophy of science and related disciplines revolve around reaching the right kind of balance between these constituents of meta-culture.

I would like to conclude the paper with calling attention to three more implications of the 'science = technology + philosophy' thesis. First, sciences are often "technicalized", meaning that their philosophical dimensions are disregarded or eliminated. Technicalization may also take a weaker form, that of an excessive emphasis on epistemology to the detriment of ontology. In both cases, the underlying motivation is the perceived need for an ideology-free science. (According to our analysis, there is of course no such thing). On the other hand, the fragmented world of the postmodern age leads to the emergence of postmodern science, which is a very technicized one, like computer and information science and technology.

If on the other hand it is the technological constituents that are eliminated from science, the complicated role of philosophy in scientific praxis becomes more salient. The scandalous Heideggerian statement that "science does not think"[15] can be interpreted as a straightforward implication of our thesis: technicized science indeed does not think, but true science (that which includes philosophical components) does. Normal science—in the Kuhnian sense of the term—does not think (although normal scientists do), only revolutionary science does.

Lastly, the thesis has important consequences for the concept of *technoscience*. On the account proposed here, all science is technoscience; there is no science without technological components. On the other hand, all science is *philoscience* as well; there is no science which would not include philosophical principles. When we speak about "science", unqualified, this inner structure of scientific knowledge remains obscured. It is always a fusion of technological and philosophical components that results in the formation of a "scientific matter", i.e., a concrete socio-historical form of science.

15 See Martin Heidegger, *What Is Called Thinking?* (New York: Harper & Row, 1968).

The relative weight of technological and philosophical components in the mixture, and the level of their integration are challenges to be taken up by the history and philosophy of science and technology, and by further studies on the interrelatedness of technology, science, and philosophy.