Chapter 22
On the Hazardousness of the Concept 'Technology': Notes on a Conversation Between the History of Science and the History of Technology

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Abstract Historians of science and historians of technology have recently turned their attention to the conceptual history of 'applied science' and 'technology' respectively. 'Technology' was a concept introduced in the nineteenth century as concerning both 'applied science' and 'industrial arts.' A developed version of this concept caught on after the first decades of the twentieth century, following the establishment of technological networks and the rise of 'Fordism,' 'Taylorism' and 'technocracy.' Based on interpretations of the nineteenth-century circuit of the steam engine and the twentieth-century network of electric power, this chapter brings together observations from the history of science, the history of technology and the critique of classic political economy to elaborate on the suggestion that 'technology' has been a 'hazardous' concept. Central to the argument of the chapter is the retrieval of a correspondence between the conceptual couples 'technology'-'-technics' and 'surplus value'-'value.'

Keywords Technology • Applied science • Fordism • Taylorism • Technocracy

22.1 Introduction

Historians of technology are no longer obliged to prove that technology has been as noble as science, while historians of science do not have to worry if it turns out that science has been involved in non-noble work. The two fields can now advance by jointly researching the historical differences between science and technology without assuming beforehand what these differences are. This was not always the case. Historians of science initially assumed that technology was 'applied science'. Being nothing more than applied science, technology did not have a right to its own

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history. Unsurprisingly, following the break in the late 1950s with the history of science and the efforts to institute and establish their specialty as a distinct field, historians of technology of an earlier generation spent much of their energy arguing that technology is not applied science. Things have certainly changed since then. While historians of science and historians of technology now agree that technology is not applied science, they take issue with the persistent appeal of the rhetoric of presenting technology as applied science. In this chapter I register some notes on this issue by way of contributing to an ongoing conversation between historians of science and historians of technology.[1]

To understand why technology has been presented as applied science, historians of technology have started paying attention to the history of the concept 'technology'. It also helps that historians of science have started to research what 'applied science' actually was. Recently (2012), a special issue of *ISIS*, the journal of the History of Science Society, offered a critical survey of the historiography of both the history of the concept 'technology' and the history of the concept 'applied science'. Those who follow this historiography from the perspective of the history of technology seem to agree that a key contribution is that of Leo Marx, who has argued that the concept 'technology is a "hazardous" one. Here, I elaborate on the argument about the hazardousness of the concept 'technology' by retrieving a correspondence between this concept and the concept of 'surplus value' of another Marx, Karl. I think that it makes it all the more interesting to know that Karl Marx himself experimented with the use of the initial version of the concept 'technology', which he juxtaposed to the concept 'technics', so as to reinforce the difference between the concept 'value' of classic political economy and his own key concept, 'surplus value'.[2]

[1] For those who want to follow the development of the historiography of technology, there are, for example, the accounts by Eugene Ferguson (1974), Reinhard Rürup (1974), John Staudenmaier (1985) and Alex Roland (1997). The assumption that technology is applied science could not be sustained once the attention was shifted from the moments of the invention of technology to its long-term use. The reconfiguration of technology in use involved hardly any science. Influential here has been an article by David Edgerton (1999). For equally insightful articles, see the ones by Carol Purcell (1995) and Ruth Cowan (1996), which show that the shaping of technology in use is inherently a process of construction of gender. A balanced integration of constructivist approaches to the historiography of technology has certainly contributed to opening up the definition of technology beyond the limits set by those who assumed that technology is applied science, Staudenmaier (2002, 2009), Tympas (2005).

[2] On the history of the concept 'technology' and/or the meaning of 'applied science', some of the most valuable contributions are authored by Ronald Kline (1995), Wolfgang König (1996), Leo Marx (1997), Ruth Oldenziel (1999), Eric Schatzberg (2006, 2012), Carl Mitcham and Eric Schatzberg (2009), Jennifer Alexander (2012), Robert Bud (2012), Graeme Gooday (2012) and Paul Lucier (2012). Earlier attempts at a history of the concept 'technology' include the ones by Graham Hollister-Short (1977) and Jean-Jacques Salomon (1984).

22.2 'Technology' as the Science of Classification of Equivalent Arts

The concept 'technology' was introduced in the nineteenth century in countries where industrial capitalism was advanced in connection with what was then called 'industrial arts'. Industrial arts were not like the 'mechanical arts' of the past. For one thing, unlike the mechanical arts, the industrial arts did not include painting and sculpture. Following the split between 'fine arts' and 'vulgar arts', industrial arts would have been vulnerable to being placed on the side of what was devalued as vulgar. This was avoided by connecting industrial arts to 'applied science'. But, of course, there could be no talk about 'applied science' before the establishment of the concept 'science', which also took place in the nineteenth century.[3]

Eric Schatzberg summarizes our present knowledge of the history of the relations between these concepts nicely when he writes that in the context of a nineteenth-century rhetorical drive aiming at transferring agency from art to science, the discourse of pure and applied science dispensed with the need to address the mechanical arts at all. 'Industrial arts' remained common until World War I (this changed with the emergence of 'Taylorism', see below). Flexible as the concept 'applied science' was, it could refer either to an independent body of artisanal knowledge or to an application of the principles of science to practical problems. Schatzberg explains that this flexibility allowed it to do boundary work for both engineers and scientists at the time when both were stabilized as professions in the second half of the nineteenth century. As demarcated from art, 'science', and therefore 'applied science' too, would be disassociated from workers (Schatzberg 2012).

It was not until the 1930s that 'technology' was put into wide circulation. Between the 1860s and the 1930s, the meaning of the concept was developed. Schatzberg is correct in arguing that 'technology', as first introduced, was an obscure concept. In most cases, this concept referred to the 'science of the arts', with science perceived here as the possibility of a uniform classification of the arts. This can be confirmed by the Greek case. The concept 'technology' was used in a 1864 Greek educational book to indicate the possibility of placing previously unconnected arts under one classification scheme. The early association between 'technology' and the attempt to place the arts under one classification merits special notice. We now know that no scientific classification is neutral. Classifications come with consequences. For one thing, when something is successfully drawn into

[3] For scattered and rather experimental uses of 'technology' before the nineteenth century, see the review of Carl Mitcham and Eric Schatzberg (2009). The *Oxford English Dictionary* credits the naturalist-theologian William Whewell with the introduction of the term 'scientist' in 1834. Before then, 'science' was used to signify any knowledge that was well established.

some classification, it enters into a minimum of equivalence to everything else that has fallen under the same classification.[4]

In this case, the classification of the arts advanced by the concept 'technology' was inseparable from the attempt to establish an equivalence of exchangeable commodities at a market determined by the industrial-capitalist mode of production. Without such classification, it would have been impossible to move on to present as equivalent social experiences that were previously unconnected. We can argue so based on an interpretation of the steam engine, the paradigmatic modern machine. The circuit of the steam engine did indeed institute equivalences between different arts. For example, it made equivalent the art of feeding a boiler and the art of moving a loom while it simultaneously established an equivalence between the coal that fed the boiler and the textile produced at the loom. Moreover, it produced an equivalence that could extend from, for example, the boiler feeder to the loom operator, and from the coal miner to the cloth maker and further. Those standing at the two ends became connected by what the theory of value of the classic political economy defined as 'labor'. As is well known, from Adam Smith to David Ricardo, classic political economy came to argue that the source of 'value' is not land—as with the physiocrats—but labor. And as we saw, without the circuit of the steam engine that connected the arts at the material level, this argument would have been impossible.[5]

'Technology' is a concept that appeared in response to (and in support of) the interconnection of the arts, on the grounds of equivalent labor. At the time, there was no definite concept of science to determine the shaping of the concept 'technology'. The two concepts developed in synergy. To indicate how, let us observe that at roughly the time when 'technology' was introduced to replace the 'industrial arts', 'science' was introduced to replace 'natural philosophy'. The transition from natural philosophy to science overlaps with the transition to thermodynamics. The key concept of thermodynamics, 'energy', was brought forward to establish the equivalence of heat and motion, which was not covered by Newtonian physics. In this sense, the use of the concept 'science' came to signify a critical enlargement of the range of equivalent natural phenomena, while the use of the concept 'technology' came to signify the equivalence of all industrial arts.[6]

[4] The 1864 Greek book on 'technology' was authored by Dimitrios Apostolidis. On the normative dimensions of classification, see the relevant argument by Geoffrey C. Bowker and Susan Leigh Star (2000).

[5] For the emergence of the classic political economy and its labor theory of value, see the clarifications offered by John Milios (2009).

[6] The kinetic theory of heat had prepared for the equivalence between heat and motion. The development of thermodynamics and the use of the concept 'energy' marked the establishment of this equivalence. For an introduction to the history of thermodynamics as a socially situated science, see, for example, a perspective offered by Faidra Papanelopoulou (2008).

22.3 ‘Technology’ After the Drive for ‘Scientific Management’

We can now turn to the meaning of ‘technology’ as it had developed by the 1930s, which is actually the meaning that allowed for the massive use of the concept. By then, the electric power networks had been firmly established through an expansive reproduction of the technical pattern introduced by the steam engine. Many engineers argued about continuity between such mechanical and electrical engineering artifacts as steam engines and electric dynamos. In the context of this continuity, a dynamo with an electric power transmission line was perceived to be analogous to a steam engine with very long energy transmission rods. The transformation of the circuit of the steam engine overlapped with the expansive use of the concept ‘energy’ so as to obtain the much broader reach of an electric power network. Between the 1860s and the 1930s, the concept ‘energy’ was developed to include in the equivalence not only heat and motion, but also electricity and mass. Kelvin’s concept of ‘energy’ is associated with the circuit of the steam engine, while Einstein’s is associated with the much larger circuit of an electric power network (which represented the expansive reproduction of the steam engine circuit through a network like the electric power transmission grid). In short, while the 1860 version of ‘technology’ referred to the material and social equivalence introduced by the relatively local circuit of the steam engine, the 1930 version covered the more global equivalence of an electric power network (and other networks such as transportation, communication, etc.).[7]

‘Technology’ started as a concept pointing to the potential of material and social equivalence through the 1860s science of classification, but it was put into mass use when this equivalence became broader: when comparatively isolated circuits became interconnected networks by the 1930s. ‘Technology’ is a concept that was introduced when the First Industrial Revolution (steam) was established, but obtained the meaning allowing for its generalized use after the establishment of the Second Industrial Revolution (electricity). Leo Marx has suggested that ‘technology’ was a concept that came to cover the “semantic void” that emerged when the available concepts could not capture the change in the material environment brought about by the Second Industrial Revolution. If my above line of reasoning is correct, it may be more appropriate to replace the argument about a semantic void by a more dialectical explanation: the concept ‘technology’ was developed in

[7] There is much known about the continuity between mechanical and electrical engineering through the work of Stathis Arapostathis (2008). On the broader continuity of mechanical, electrical and electronic engineering, see my argument in (Tympas 2007). For the influence of the emergence of technological networks in Einstein’s concept of ‘energy’, see the history offered by Peter Galison (2003). A very useful history of the history of the transition from steam engines to electric power networks has been written by Louis C. Hunter and Lynwood Bryant (1991).

reaction to the successful development of industrial capitalism from the First to the Second Industrial Revolution.[8]

Between the 1930s, when the use of concept 'technology' started to become popular, and the 1860s, when an initial version of it was introduced, the mode of production based on the use of a technical pattern set by the steam engine—the industrial-capitalist mode of production—succeeded in undergoing a double expansion. Inside the factory, it grew toward more specialized machines and correspondingly unskilled workers. This is known as 'vertical integration'. At the same time, there was an attempt at a 'horizontal integration': inputting only raw materials at one side and integrating marketing with production at the output side. This two dimensional integration took place under the combined influence of what became known as 'Fordism' and 'Taylorism', respectively.[9]

Henry Ford was not the only one who cared about generating a mass demand to match the mass supply of products manufactured in his factories. Samuel Insull, who had started as Thomas Edison's secretary before moving on to financially control an empire of electric power utilities, had the same concerns. Insull realized that to make the most profitable use of electricity supplying (generating) factories there had to be constant demand for electricity. Ford himself symbolizes the enlargement of the mass-producing factory to its limit. In comparison, Insull symbolizes a version of Fordism that referred to the network that grew together with the Fordist factory. This was the network formed by the lengthening and interconnection of the lines connecting the mass-producing factory to mass consumption. It is only after the establishment of the unit formed by a mass-producing factory like Ford's and a massive network like Insull's that the concept 'technology' started to be used on a massive scale.[10]

Fordism was complemented by Taylorism. Fordism could open the factory up to the motion of special purpose machines only as long as Taylorism could make space by controlling the movements of the workers. Similarly, Fordism could rely on skills embedded in machines only as long as these skills could be extracted from those who would work them. This is what Taylorism sought to do. Yet, de-skilling at one level went hand in hand with re-skilling at another. The other face of the formation of a pyramid of workers was the formation of a pyramid of engineers. No one was actually unskilled. But relative differences in skill were ideologized as being absolute. In reality, skill has been indispensable to profit. Skill was the source of profit. Skill, however, could be rhetorically neglected by presenting the machine as the source of value, therefore paying less for skill and making more profit. This is

[8] The development of the meaning of 'technology' over the course of the Second Industrial Revolution was associated with a shrinking in the meaning of the concept 'arts'. As the arts were devaluated in comparison to both industry and science, the meaning of 'technology' came to cover both the industrial arts and applied science. On this point, see (Schatzberg 2012). For Leo Marx's argument about a "semantic void", see (Marx 1997).

[9] A classic history of these changes is given by David Hounsell (1991). On the limits to Fordism, see the work of Phil Scranton (1997).

[10] For an introduction to Insull, see that of Thomas Hughes (1989).

what the rhetoric of Frederick Taylor was all about. Skill points to art. Taylorism was about replacing the arts with science. Self-presented as 'scientific management', Taylorism sought to advance a science of the arts that would be independent of the workers. This is just like the industrial arts as connected with applied science. Taylor's definition of 'scientific management' was an aggressive version of what was meant by 'applied science'. It was then a concept that shared its meaning with the concept 'technology'.[11]

In partnership with Fordism, the drive toward 'scientific management' gave rise to a movement called 'technocracy'. If Taylorism was about managing society at the factory level, technocracy was about managing society as the most general level: the central government. While Taylorites sought to establish an engineering rule at the factory, technocrats were pursuing the management of politics with an engineering rule. Taylorism and technocracy became popular in the first decades of the twentieth century. But, in 1929, technocracy took a hit because the US citizens had elected as president an engineer (Herbert Hoover) who failed to regulate Fordism and thus avoid mass overproduction and the unprecedented crisis that this induced.[12]

Technocracy was explicit about the connection between material and political artifacts. By contrast, the use of the concept 'technology' concealed the fact that politics is embedded in materialities. While technocracy took a strong hit by the big crash, the technocratic ideals could rely on the quickly spreading use of this concept to survive. In other words, the wide use of the concept 'technology' came to the rescue of the technocratic ideals when the politics of technocracy were proven to be questionable. Adjusted versions of these ideals became an organic part of governments throughout the world, from the United States of America of Franklin Roosevelt to the Soviet Union of Joseph Stalin, and, from the European totalitarianism of Germany and Italy to the Asian totalitarianism of Japan. To explain why Leo Marx is right in suggesting that technology is a 'hazardous' concept, I suggest that we start by noting that this concept was catching on amidst a terrible economic crisis and the devastating war that followed it.[13]

22.4 'Technology' Is to 'Technics' What 'Surplus Value' Is to 'Value'

For a further elaboration on the hazardousness of 'technology', I suggest that we elaborate on a conceptual deadlock that emerged parallel to the spread of the paradigmatic circuit of the steam engine. As mentioned above, the availability of this circuit made it possible to argue for a general equivalence of the arts, which

[11] The most influential study of Taylorism is, perhaps, that of Harry Braverman (1974).

[12] For a relevant history of engineering, see the classic by David Noble (1977).

[13] On the international spread of 'Americanism' (the Fordism-Taylorism mix), see (Hughes 1989).

brought forward the labor theory of classic political economy. The spread of steam engines, paralleling the advance of this theory from Smith to Ricardo, established the attribution of value to labor. While this theory demanded that it was labor and not land that produced value, it could not answer the question regarding the role of the machine in the making of value. For classic political economy, it is labor and not the machine that produces value. But classic political economists had to acknowledge that the machine, too, was somewhat involved in the process of production of value. Yet, at the same time, they insisted that labor could be the only source of value. This was then the constitutional ambiguity of classic political economy: the availability of machines clearly affected the production of value, yet the only source of value was labor (Milios 2009).

This ambiguity, I think, is a manifestation of the infamous 'machinery question' of the nineteenth century. Historian Maxine Berg has shown how important this question was for both nineteenth-century British society and for classic political economy (Berg 1980). As early as 1929, in his masterful *A History of Economic Thought*, Isaak Rubin had shown that the concepts of classic political economy could not address this question. This would require a concept that could open up the possibility of a break with classic political economy. This was precisely what Karl Marx's concept 'surplus value,' was all about. It was introduced in a book subtitled *A Critique of Political Economy*. 'Capital', the concept that gave the title to the same book, was about the self-propelling accumulation of surplus value. To better understand the difference between the concepts of classic political economy and the concepts of its Marxian critique, let us turn once more to the circuit of the steam engine.[14]

Through the use of the circuit of the steam engine, heat was made equivalent to motion. But the flow in the circuit of the steam engine was one directional: from heat to motion. It was designed to produce textiles from coal. One could not use the same circuit in the reverse to produce coal from textiles. Coal and textiles could be exchanged outside the circuit of the steam engine, outside the factory. Inside the factory, using the circuit of the steam engine, only textiles could be produced. The machine and its factory represented a one-directional flow toward an irreversible production, not a reversible two-directional exchange. In the language of the science of thermodynamics, the quantity of energy was equal at the two ends of the steam engine, but the quality was not. The two were not then of equal value. The mediation of the steam engine meant production of extra value and not just an exchange of equal values. Industrial production meant a loss of energy quality for a gain in value.

The second law of thermodynamics laments this loss of available energy (and worries about it) as an irreversible loss in nature. It was indeed a loss of labor, of human or other agents of nature (in the context of the science of thermodynamics

[14] On the Marxian concepts, see (Milios 2009).

there was an increase of 'entropy').[15] But as an industrial process, this natural loss came with an increase in social value. The classic political economy could not theorize this increase in value because it assumed an equal exchange of it. It looked at the economy from outside the factory. This view black-boxed the steam engine in a manner that concealed how laboring with it resulted in an increase of a value. Classic political economy lingered at the exchange part of economy: the market value. It did not consider the part of the economy dealing with machine production: the surplus value (the capital). This is why its concept, 'value', was marked by an ambiguity in regards to the machine. This is why the machine was a problem for political economy.

At the climax of the 'machinery question', which could not be addressed by the concept of value, Marx did not only make use of the concept 'surplus value'. Taking note of the introduction of 'technology', he used this concept to further point to what political economy could not see. As Guido Frison has observed, in a revised edition of *Capital*, Marx differentiated between 'technics' and 'technology'. According to Marx, the two were referring to the same process viewed from different angles. When a factory steam engine was viewed from the perspective of the material artifact that made two arts equivalent, he wrote of 'technics'; when the same was viewed from the perspective of the science that made such equivalence possible, he wrote of 'technology'. The new concept, 'technology', seemed very appropriate for such differentiation. Technology was technics inseparable from logos (techno-logy). It was a concept to acknowledge that materialities are inseparable from discourses.[16]

I think that technology was to technics what surplus value was to value. Marx introduced the concept 'surplus value' to point to the ambiguity of the theory of value—to show what was concealed by the concept 'value'. The new concept, 'technology', offered him an opportunity to point to the same ambiguity at the level of the conceptualization of the material practice referred to by this theory. Both the 1860s and the 1930s version of 'technology' were about the inseparability of a discourse about material artifacts and material artifacts themselves. Karl Marx used the 1860s version of the concept to be explicit about the discourse from science that could lead to an understanding of how materialities contain socialities. By the

[15] The opening paragraph of the infamous *On the Age of Sun's Heat* by Sir William Thompson (Lord Kelvin), which was published in Macmillan's Magazine on March 5, 1862 (vol. 5, pp. 388–393), touches on this irreversible loss in nature, which would lead to death if the universe were not finite: "The second great law of thermodynamics involves a certain principle of *irreversible action in Nature*. It is thus shown that, although mechanical energy is *indestructible*, there is a universal tendency to its dissipation, which produces gradual augmentation and diffusion of heat, cessation of motion, and exhaustion of potential energy through the material universe. The result would inevitably be a state of universal rest and death, if the universe were finite and left to obey existing laws."

[16] For Guido Frison's observation, see (Frison 1988). For a further contextualization of this, see other articles by Frison (1993a, b, 1998) and by Fumikazu Yoshida (1983a, b). Little has been written on Karl Marx in history of technology journals. For one of the few exceptions, see the 1984 article in *Technology and Culture* by Donald Mackenzie (1984).

1930s, the discourse of 'science' that was influencing the concept 'technology' was determined by the 'scientific management' rhetoric of Taylorism. This rhetoric, which we find in the 1930s version of the concept 'technology,' was tailored to conceal the fact that materialities contain socialities. The concept Karl Marx had tried because he thought it was promising had been developed into the concept Leo Marx has aptly called "hazardous."

22.5 Addendum: On Central and Peripheral Historiographical Issues

To add support to the call for research on the emergence and development of the concept 'technology' in the modern period, we may also consider the implications of the absence of such a concept before modernity. The realization that 'technology' did not exist as a concept before modernity invites us to question if there can be such a thing as a history of technology in antiquity or in any other pre-modern historical period, western or not. If the answer is yes, how do we produce meaningful analogies between modern technology and its historical counterpart in another period (whatever that may turn out to be)? In pursuit of such analogies, it seems to me that we need to revisit the answers to some of the foundational questions of historiography of technology. Consider, for example, the question posed in *Does Technology Drive History? The Dilemma of Technological Determinism*, which was edited by Leo Marx and Merritt Roe Smith (1994). Would it be meaningful to raise such a question in the context of the historiography of antiquity? And is there a dilemma about technological determinism in antiquity?[17]

In regards to modernity, the dilemma of technological determinism is a different manifestation of the ambiguity of the classic political economy that this chapter has argued about. It follows that the hazardousness of 'technology' has to do with the way the use of the concept allows for the hegemony of the ideology of technological determinism. Considering the correspondences between this concept and that of 'surplus value', technological determinism can be interpreted as the key ingredient of an ideology that the *Capital* introduced as the 'fetishism of commodities'. We saw how important to this ideology is the vulgar presentation by 'scientific management' of materialities as independent of socialities.

Having touched on the similarity between technological determinism and the ambiguity of classic political economy, I will conclude by registering one last note regarding the absence of the concept 'technology' before modernity. The concept 'technology' was not used, for example, in Greek antiquity or during the Byzantine period. It follows that those who profess to practice the history of technology in these periods have to be explicit about the concepts (if any) they consider to be

[17] A suggestive update on the persistence of technological determinism is given by Sally Wyatt (2008).

equivalent to the modern concept 'technology'. A historian who specializes in the study of technology in modernity in a country like the US is not directly challenged to pose this question or respond to it. After all, there is no such thing as the history of the US in antiquity. The same is the case with any other country that has a history fully contained by the modern period. But the issue cannot pass unnoticed in reference to a history about Greece (or, to take the example of the world's most populous country, China).[18]

Distinguished scholars of technological determinism, from Leo Marx and Merritt Roe Smith to Bruce Sinclair and Joseph Corn, have assumed that technological determinism is about rhetorical constructions of a glorious technological future. However, as ongoing research on the history of technology in modern Greece has shown, technological determinism can actually be based on rhetorical constructions of a glorious technological past, that of ancient Greece. For example, as Spyros Tzokas has argued, the founding members of the modern community of Greek engineers were promoting the most technocratic visions regarding the technological infrastructures of modern Athens by arguing that the glory of ancient Athens was actually due to its technological infrastructures. For them, modern Greece would become glorious only as long as it could invest in a future technology that would be as advanced as ancient Greek technology was in the past. Unavoidably then, those who wish to study the history of technology in modern Greece are obliged to be explicit (and convincing) about the macro-historical periodization which subsumes their study of the history of technology in modernity.[19]

The Greek case suggests that it is not only the proper study of the history of technology beyond modernity that is at stake here. It is also the proper study of the history of technology in modernity, with the latter feeding on the former. If this is the case, a seemingly peripheral issue concerning the practice of history in (and about) Greece may have a more central historiographical message to deliver. As Kostas Gavroglu has argued, any historiography of science and technology in the peripheries would manage to address central historiographical questions only to the extent that it could begin to question the very definition of center and periphery. If this chapter manages to somehow help the history of science and technology move to the center of the constellation of historical specialties, it is because of Kostas Gavroglu's masterful and tireless teaching on how to reevaluate the periphery.[20]

[18] For a history of technology in antiquity that is sensitive to concepts, I recommend that of Serafina Cuomo (2007). The importance of the Chinese case is convincingly argued by G.E.R. Lloyd (2004).

[19] For a first attempt at such periodization, see (Tympas 2002). For a sample of studies on the futurism of technological determinism, see (Sinclair 1986; Corn 1988, 1996; Marvin 1990; Wright 1992; Nye 1994; Corn and Horrigan 1984). For the construction of a history of technology in antiquity by modern Greek engineers and its integration into technological determinism, see (Tympas et al. 2005).

[20] Gavroglu et al. (2008).

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