A Companion to the Philosophy of Technology

Edited by

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History of Technology

THOMAS J. MISA

A generation ago, before the much-noted "empirical turn" in philosophy, it was unlikely that an assessment of the philosophy of technology would have prominently featured the history of technology. Put simply, there were relatively few common concerns, since historians of technology rarely engaged in the sort of questions that animated philosophers of technology. Consulting the published volumes of *Research in Philosophy and Technology* and *Technology and Culture* three decades ago suggests two divergent scholarly communities, separated by research methods and background assumptions, and pursuing largely independent investigations. At the time, historians of technology were insisting on technology being an ontologically and epistemologically separate category from science, and vigorously insisting that technology is not merely applied science, while philosophers were ready and more comfortable with sweeping normative assessments about the essential characteristics of technology and its impact on society. In the debates on technological determinism, philosophers of technology and historians of technology were nearly as far apart as possible: while historians of technology adamantly refuted any and all claims of technological determinism, philosophers of technology were as a discipline the most enthusiastic in exploring and embracing the notion that technology determines social and cultural change and that technology develops more or less autonomously of social and cultural influences (Winner 1977; Misa 2004b). In this climate, there was not so very much that the two specialist fields held in common.

In the last ten years or so, however, there has been increasing mutual interest in philosophy and history of technology (Achterhuis 2001; Ihde 2004). It has not been that a hybrid discipline such as the history of philosophy of science has emerged, but rather that some historians and some philosophers have discovered common interests and common concerns. The essays in this volume are testimony to this shared mutual interest, although the individual topics they explore do not really exhaust the range of shared topics and emergent themes (see Misa et al. 2003). The commissioned essays examine the cultural contexts of technology, notably in the specific contexts of Japan, Islam, China and the West, as well as examining the problem areas of defining technology and assessing military technology. These essays develop some of the shared concerns and concepts that are emerging between these two fields. Accordingly, this essay will provide a summary of their main findings but also attempt a wider assessment of

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these shared concerns and emerging problems. I shall do so by accenting three themes: the challenges of defining the term “technology”; the varied concepts and problems in defining “culture” as well as its relations to and interactions with technology; and the issue of technological determinism, a scholarly and practical problem that, for several decades, has merited philosophical reflection and historical analysis.

Definitions of “Technology”

Historians of technology have for many years pointedly resisted giving a prescriptive definition of the term “technology.” This stance, somewhat paradoxically, reflects the disciplinary maturity and confidence of their field. They have frequently observed that no scholarly historian of art today would feel the least temptation to try to define “art,” as if that complex expression of human creativity could be pinned down by a few well-chosen words. And similarly, as the noted historian of technology Thomas Hughes has written (2004: 2), “Defining technology in its complexity is as difficult as grasping the essence of politics. Few experienced politicians and political scientists attempt to define politics. Few experienced practitioners, historians, and social scientists try to inclusively define technology.” Most historians writing on technology have defined the term mostly by presenting and discussing pertinent examples. Many historians studying the twentieth century have focused on large technological systems, such as electricity, industrial production, and transportation, that emerged in the early decades and became more or less pervasive in the West during the second half of that century.

Other historians even of the twentieth century, however, would strongly prefer to examine technologies from the perspective of “everyday life” or from a user’s perspective. Even what might on the surface be considered the same technology can look quite different when viewed “from above” using a manager’s or a business executive’s perspective or, alternately, “from below” using a worker’s or an individual consumer’s perspective. Often, the view from above leaves the impression of large systems spreading more or less uniformly across time and space – as, for instance, maps showing the increasing geographical spread of railways and highways or statistical tables showing the increasing pervasiveness of such electrical consumer goods as irons, refrigerators and televisions. Conversely, locally situated studies of individual technologies, sometimes inspired by consumption studies, often find substantial variability in patterns of use and in the meanings these technologies have for subcultures that form around them. As studies inspired by the productive “user heuristic” have shown, there is a great deal of creativity and inventiveness that is uncovered when paying close attention to these local processes (Oudshoorn and Pinch 2003; Hippel 2005). Farmers invented new uses for Henry Ford’s classic Model T automobile when adapting it for use on the farm as a source of power. Even the widely popular invention of email was at the start “unplanned, unanticipated, and most unsupported” by the original designers of the Internet (Abbate 1999: 109). Japanese teenagers created new uses for mobile pagers and cell phones, and created a new culture in doing so (Ito et al. 2005). Many times these activities, not originally conceived by the system designers, can be taken up by the producers of these devices and systems and transformed into economically lucrative marketing strategies. This finding of substantial diversity has implications beyond merely complicating any tidy definition of technology; this diversity, especially the agency of users in divining and defining new purposes for a certain technology and new activities around it, also keeps open the question whether technologies can meaningfully be said to have "impact" on society and culture. Normative evaluations of technology, then, cannot assume that the meanings or consequences of technology can be easily comprehended; nor, as was once the case in the early days of the technology-assessment movement, can these characteristics be predicted from the technology's "hardware" characteristics. Indeed, all assessments of technology need to grapple with these epistemological and methodological problems.

Indeed, recent research has productively treated the term "technology" as an emergent and contested entity. Technology is not nearly as old as we commonly think, especially if we have in mind the several technologically marked historical epochs, such as the Bronze Age or the Iron Age. Jacob Bigelow, a medical doctor and Harvard professor, is often credited with coining the term in his book *Elements of Technology* (1829). "The general name of Technology, a word sufficiently expressive . . . is beginning to be revived in the literature of practical men at the present day," he wrote (Bigelow 1829/1831: iv–v). "Under this title it is attempted to include . . . an account . . . of the principles, processes, and nomenclatures of the more conspicuous arts, particularly those which involve applications of science, and which may be considered useful, by promoting the benefit of society, together with the emolument of those who pursue them." Earlier than this, the term "technology" in English, as well as its cognates in the other principal European languages, referred most directly to the treatises and published accounts describing various technical crafts. Bigelow's own coinage did not immediately catch on, however. His speech to the Massachusetts Institute of Technology more than three decades later helped recast the term as an aggregate of individual tools and techniques, an agent of progress, and an active force in history. "Technology," he asserted in 1865, "in the present century and almost under our eyes . . . has advanced with greater strides than any other agent of civilization, and has done more than any science to enlarge the boundaries of profitable knowledge, to extend the dominion of mankind over nature, to economize and utilize both labor and time, and thus to add indefinitely to the effective and available length of human existence" (Segal 1985: quote 81).

Following Bigelow's use, "technology" gained something of its present-day associations in the next several decades. Numerous institutes and colleges of technology in the United States took up the name: not only the flagship of MIT (founded 1861) but also other colleges, schools, or institutes of technology such as Stevens (1870), Georgia (1885), Clarkson (1896), Carnegie (1912), California (1921), Lawrence (1932), Illinois (1940) and Rochester (1944). Polytechnics in Europe, often modeled on the pioneering École Polytechnique (founded much earlier, in 1794) in Paris, provided broadly similar educational opportunities. In 1950, the Indian government founded Kharagpur Institute of Technology, the first in a national network of seven technical universities.

As Ruth Oldenziel (1999) has made clear, in these same decades "technology" took on a distinctly male-oriented slant. Earlier terms such as "the applied arts" or "the industrial arts" could be associated equally with the products of women's work as with men's; but "technology" after 1865 increasingly came to signify male-oriented machines and industrial processes. Oldenziel sees the emergence of technology in the personification of the (male) engineer as an instance of the gender-coding of the modern world. Eric

Schatzberg situates the rise of "technology" as a keyword in the writings of social critic Thorstein Veblen, who drew heavily on the contemporary German discourse around "technik," as well as of the popular historian Charles Beard. "Technology marches in seven-league boots from one ruthless, revolutionary conquest to another, tearing down old factories and industries, flinging up new processes with terrifying rapidity," in Beard's arresting and deterministic image (Schatzberg 2006: 509). Also following Raymond Williams's method of keywords, Ronald Kline (2006) examines origins of "information technology" in the management-science community of the 1960s and its subsequent spread into the wider discourse.

Recently, the term "technoscience" has found favor in the writings of some, if not all, philosophers of technology and historians of technology. Advocates of the term maintain that the practices, objects and theories of science and technology, even if they once were separate professional communities, have blurred to a point at which they share many important features – indeed, to a point at which their similarities outweigh their differences. The term is not merely a recognition that biologists today frequently enough apply for patents and create start-up companies; it also draws attention to hybrid forms of knowledge and practices. (As such, the appeal to hybridity is an important aspect of the anti-essentialism that is characteristic of much recent technology studies.) With a tone of caution, Barry Barnes (2005: 155) writes of "near consensus on the predominance of technoscience as something characteristic particularly of recent times." Philosopher of technology Don Ihde's *Instrumental Realism* (1991) presented an extended analysis of Latour's *Science in Action* (1987), in which "technoscience" was defined and popularized.[1] And, similarly, Ruth Cowan's *Social History of American Technology* (1997) takes up "technoscience" in her final chapter, using the examples of hybrid corn, penicillin and the birth-control pill. Overall, historians conceptualize technology as contingent, constructed and contested.

Problems of Culture

In making their assessment of the "anthropological variety" of technology (see Li-Hua), the essays of this section attempt to identify and describe the core qualities that can be associated with Islamic, Chinese, Japanese and Western technology. These essays utilize the familiar method of defining by example and discussion, and there is much to be learned from the rich empirical diversity that such an overview provides. It is worth marking at the onset, all the same, that each of these essays takes up a more-or-less bounded and non-problematic analysis of the assigned "culture." This is especially the case, somewhat paradoxically, when the essays examine instances of the transfer of technology between regions or cultures. Even the idea of a technological "dialogue" between different cultures (used to good effect by Arnold Pacey [1990]) can still carry the assumption that there exists a fundamental, identifiable and more-or-less essential core to the culture(s) under examination. Recently, anthropologists and social theorists have preferred to jettison such essentialist conceptions of culture, and to prefer performative ones. Here, there is no stable core to a given culture – i.e. its essential features – that is constant across time and then that might "change" under one set of circumstances or another. A performative view postulates that cultures are continually re-created and performed, so that changes can be small and incremental and/or large and dramatic. Performative conceptions of culture are also helpful in identifying cultural hybridities, where cultural productions take up and incorporate novel elements which may have their origins in "foreign" borrowings but also with "domestic" innovations.

On the surface, Japan might seem a reasonable candidate for an essentialist understanding, owing to its geographic separation and strong cultural identity. What we might today consider to be "quintessentially Japanese" came rather late to Japan. As David Wittner shows, Japan for many centuries received transfers and/or engaged in technological dialogue with China and Korea, the sources of wet-field agriculture, of the basic techniques of working bronze and iron, as well as of weaving, silk, paper and more. Wittner suggests that, beginning in the eighth century, Japanese woodworking, printing, metalworking and other crafts diverged from Chinese practices. The rise of urban centers of innovation in the late Heian period (794–1185) led to distinctive Japanese practices in jointless carpentry, as well as in standardized interior spaces signified by uniform-sized tatami mats. Metal-based military innovations came to the fore during the Warring States period (1467–1568), notably in the fields of sword-making and gun manufacture.

Two prototypically "Western" technologies that were introduced into Japan in the mid-sixteenth century provide an apt way of assessing Japan's remarkable technological sophistication. Gunpowder weapons arrived in Japan in 1543 after a Portuguese ship was wrecked off the coast. It happened that the Portuguese survivors landed on the small island of Tanegashima, that this island was rich in iron ore and consequently also in metalworking skills, and that its local lord commanded one of his artisans to make a copy of a Portuguese gun, achieved in short order, and that this region of Japan was well connected to the mainland through trade and tributary relations (see Lidin 2002). The result was that within three decades Japan was making very large numbers of these muskets, with specially modified firing-lock mechanisms and extra attention to effective waterproofing. Muskets, numbering in the many thousands, played a decisive role in the battle of Nagashino (1875), a turning-point in Japan's political history that led to the consolidation of power by the Tokugawa shogunate (1600–1868). A battle in 1600 is believed to have featured 20,000 muskets.

Western-style mechanical clocks arrived in Japan in 1551, introduced by Jesuit missionaries. In his essay Wittner rightly stresses the unprecedented mechanical complexity of the mechanical clock, and perceptively suggests that its mastery by Japanese artisans forms an important resource for Japan's later industrial prowess with mechanized reeling machines and looms. It also should be emphasized that Japanese artisans invented an entirely distinctive type of clock, which married the mechanical regularity of its interior clockwork mechanism with several ingenious schemes for relating this mechanically uniform time to the seasonally varying hours that typified Japanese concepts of time. There were six equal units of Japanese time between local sunrise and sunset, and also six units between local sunset and sunrise, the length of which then varied by the season. To devise clocks, including automatic bell-striking ones, that would vary the effective length of the hour seems a compelling instance of a thoroughly "hybrid" technology, and certainly not merely an adaptation or transfer of a Western one. Japan persisted with its distinctive, non-Western time-keeping system until 1873, when during the modernization of the Meiji era (1868–1912) the country converted to a Western calendar and Western time practices amid a great number of other Western-inspired institutional changes. Indeed, it may be that the development of "Japanese" identity was a cultural response to the coming of modernity (Caldararo 2003: 465).

The technological and cultural variability one confronts in examining China and Islam is even much greater. As Thomas Glick points out, the "Islamic technology" he surveys is really the technological and scientific knowledge characteristic of the classic Islamic Arab civilization. At its peak in the eighth century, and continuing until 1492, the political and cultural influence of Islamic Arabs extended through North Africa and into present-day Spain. This is why one finds Islamic technology in eastern Spain in the form of so-called Persian-style *qanat* irrigation techniques as well as water-raising *noria*. From the thirteenth century, gunpowder weapons, too, were subject to a wide-ranging geographical transfer process as the Mongols transported this Chinese technology westward with devastating effects. Glick appropriately situates his discussion of Islamic technology in the context of wider continent-scale flows of knowledge and techniques, including the movement westward of the Indian style of agriculture (involving a "distinctive roster" of citrus fruits, rice, sugar cane and cotton) and the diffusion to the Islamic world of Greek astronomy and Indian astronomical tables and instruments. One culturally distinctive set of practices involved the computation of special tables to identify the direction of Mecca as well as accurate timekeeping to mark out the five daily prayer times. Yet, as Glick (1996) and others have recently suggested, "Islamic" technology may also be more of a "hybrid" than a brief overview is able to convey. The specific forms of irrigation in medieval Valencia, for instance, may reflect North African influences and models as much as Arab ones.

Compared with the essays on Japan and Islam, Francesca Bray's essay on Chinese technology is certainly less affected by any sort of essentialist assumptions about the core of China's technology or culture. As an anthropologist herself, Bray offers an essay that at once is close to Chinese assessments of technology and situates itself squarely in the context of historiographic debates on China. She is asking the questions "What do we know about China?," "What do the Chinese know about China?" and "How have the tensions and competitions of the Cold War influenced how we conceptualize China?" One consequence of the political climate of the Cold War, with its long-standing obsession with understanding and conceptualizing the supposedly technology-driven process of industrialization, was the framing and persistence of the "Needham question." Joseph Needham, the eminent British scholar, posed the question why, given China's superior attainments in science and technology – having invented gunpowder, the compass, movable-type printing, all well in advance of the medieval West – did China not also experience a large-scale transformation of its society and economy, which we in the West label as our own scientific revolution or industrial revolution.

Characteristically, however, Bray spends much more time on what Chinese people thought about their own relations to the West, rather than attempting to answer the Needham question. Across most of the entire nineteenth century, China was hard-pressed by the Western powers. Following the experience of "humiliating defeats" in the Opium Wars (1840–2, 1856–60) and the loss of sovereignty attending the forced signing of the "unequal treaties" with the Western powers, the Chinese attempted a home-grown modernization known as "self-strengthening." Despite some successes such as the

Jiangnan Arsenal in Shanghai, the efforts to build up China's economy and technological level as well as achieve a productive accommodation between "Western artifacts and Chinese spirit," the overall results were disappointing. Japan, fresh from its own Western-inspired modernization, invaded China in 1894 and forced additional territorial concessions. Given these setbacks, it was difficult for Chinese people to see and appreciate their own technological heritage; instead they conceptualized "technology" as a foreign, Western construct. Technocratic Chinese advocates of economic development in the 1930s, according to Bray, strove to emulate Western models. For much of the orthodox Maoist period (1949–78), China oscillated between grand attempts at forced-draft industrialization and the upheavals of the Cultural Revolution, with its anti-technocratic slogan "Better Red than Expert." More recently, as Bray notes, scholars of China have entirely shifted away from the comparative Needham questions and instead treated China on its own terms rather than as a reflection of the West.

Dilemmas of Determinism

Discussion of the common concerns of philosophers of technology and historians of technology must include mention of "technological determinism." As noted above, philosophers and historians have not seen eye to eye when examining the problem of whether, if and how technology brings about social and cultural changes. In their more or less essentialistic framing of the problem a generation ago, philosophers of technology were among the most enthusiastic proponents of the notion of technology as a strong and compelling force for change in history, while historians of technology took great pains to attack any and all forms of technological-determinist arguments (Smith and Marx 1994). Differences in the analytical "scale" at which scholars conduct their studies help account for these explanatory differences (Edwards 2003; Misa 2004b). The cases of military technology and Western technology, which are often cited as leading examples in assessments of the power of technology, offer rich material to explore and assess the dilemmas of determinist accounts of technology.

Bart Hacker frames his essay on "Technology and War" in an interactive framework. "The interplay of military institutions and changing technology has regularly made history," he maintains. His essay presents a richly textured account, over a very long span of human history, of these interactions. His model is that military institutions are both key sites of technical innovation and critical vectors that transport and transform technical innovations. He finds the rise of organized armies in the Near East, in Mesopotamia and in Egypt in the fourth millennium BCE to be a key turning-point that "decisively divided prehistory from civilization." Composite bows and horse-drawn chariots contributed to the effectiveness of the emerging armies, but these complex and expensive technologies required deep pockets; thus the new technologies in this way depended on the state's capability of mobilizing extensive resources. These early states clearly took form through the deployment of military technologies, while these technologies were themselves products of state initiative.

Hacker also provides a detailed account of the rise of feudalism as a social, economic and political form – arising first on the Iranian frontier – and its relation to the (again expensive) technologies of large grain-fed warhorses. Feudalism, with its "centers of local military power that regularly threatened central control," was certainly not the ideal option for a central power wishing to retain control over its lands, but in Hacker's estimation it was a social and economic arrangement necessary to field the war-winning military technology of the time. One classic technological interpretation of feudalism that Hacker does not cite in this essay is that of Lynn White (1962). White famously argued that horse stirrups, heavy plows, and mechanical power were crucial to the rise of feudalism in Europe. Even with many scholarly criticisms over the years, White's overall interpretation retains remarkable persistence among non-specialists (for a recent assessment, see Roland 2003).

A set of "revolutions" related to military technologies rounds out Hacker's treatment. Gunpowder weapons, invented in China in the late thirteenth century, had dramatic consequences for the states that embraced them. Not only were guns useful in claiming territories from lesser-armed foes; the sizable expenses required to field an army with numerous guns (as well as procuring the extremely costly gunpowder) also worked to centralize both political and economic power. These changes – clearly related to technology but certainly not caused by technology – were most evident in the classic early-modern "gunpowder empires" of the Ottomans in the Near East, the Safavids in Iran, and the Moguls in India. Intense competition between rival states in Europe, with none of them able to consolidate power over the continent, led to a period of vigorous institutional and technological innovation. The resulting "military revolution," Hacker writes, "may well have been the key factor that disrupted in the West's favor the rough parity in technology, economy, and polity that prevailed until the 15th century among civilized communities all across the Old World."

By around 1900, in the wake of military, scientific and industrial revolutions, the West's military capabilities would "achieve an almost uncontested hegemony over most of the world." As noted above, the modernizations embodied in China's "self strengthening" as well as in Japan's Meiji restoration were constructed around the adoption of Western weapons and Western models for military institutions. As Hacker concludes, "in the late 19th and 20th centuries, all armies became Western in organization, in equipment, and in spirit."

If "all armies became Western," then might it be the case that Keld Nielsen's essay on Western technology describes the paradigm toward which the world is conforming? Nielsen himself suggests that Western technology has become more or less pervasive, and can be "found on all continents." There are numerous ways in which Western and non-Western technologies share significant characteristics, but it is Nielsen's ambition to identify a number of "unique" characteristics that typify Western technologies. These include, in somewhat compressed form, the ability to extract mechanical energy from fossil fuels; the creation of integrated systems of mass production linking raw materials, production and consumers; the spread of uniform technical standards; the ability to manufacture tools and products to increasing mechanical precision; the mobilization of large capital and financing; the deployment of scientific knowledge; and a commitment to continuous "renewal" through research and development. Nielsen also allows that these immense technological capabilities have made it possible for humans to alter the world's climate or even destroy its population.

As such, Nielsen's list of unique Western characteristics is an admirable one to have identified but a difficult one to defend. One possible defense would be to assert that Western technology is typified by the *package* of these characteristics, taken together, and operating on a large and/or pervasive scale – and not by the characteristics taken individually. Certainly there is a meaningful difference in the technological capacities of, say, Switzerland and of most of the countries in sub-Saharan Africa, as measured in phone lines or Internet connections per capita, access to patents and technology, and agency in dealing with the global economy. Luxembourg has 199 phone lines per 100 inhabitants; Angola has 1.5. Maps of the global Internet, as well as composite photos of the Earth during night-time hours, also indicate that Africa as a continent is in comparative terms literally "off" the electricity and information networks.

The end of the Cold War and the rise of globalization has further blurred lines marking off the "West" and made it more difficult to defend the concept of "Western technology." A Western computer might be designed in Silicon Valley (safely in the West), but software is increasingly written by programmers in India and China, with many components of personal computers manufactured in Taiwan, Hong Kong, China and other formerly "Far Eastern" countries. According to the Basel Action Network, no fewer than 500 large containers (40 feet in length) arrive each month in the port of Lagos, Nigeria, packed with obsolete computers and other electronic equipment. While Lagos has an active market in recycling these components, up to three-quarters of the shipped material is unusable trash, in effect being dumped in Africa owing to cheap global shipping.[2] Apart from the obvious moral issues, there is a puzzle in this example concerning what is "Western" about these computers, and whether they are still fairly considered to be "Western" when manufactured in a Chinese town and then, some months later, disposed of in Africa.

Notes

1. Latour's definition of technoscience (1987: 174–5) is part of the exposition of his worldview and method, and it is not easy to summarize briefly. The relevant passage reads: "To remind us of this important distinction [the Janus-like quality of science-in-the-making compared with ready-made science], I will use the word **technoscience** from now on, to describe all the elements tied to the scientific contents no matter how dirty, unexpected or foreign they seem, and the expression '**science and technology**,' in quotation marks, to designate *what is kept of technoscience* once all the trials of responsibility have been settled. The more 'science and technology' has an esoteric content the further they extend outside. Thus, 'science and technology' is only a sub-set which seems to take precedence only because of an optical illusion."
2. <www.ban.org/BANreports/10-24-05/index.htm> (21 December 2007).

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2

Definitions of Technology

RICHARD LI-HUA

Owing to anthropological diversity, the attempt to define technology seems quite challenging. People may have different interpretations as they are positioned differently. This reminds me of the Chinese parable of the blind men and the elephant.

Megantz (2002) further elaborates in the preface to his book *Technology Management: Developing and Implementing Effective Licensing Programs* that technology is a wonderful, amazing, always changing bag of tricks that helps human beings to live healthier, happier (however, these could take place in other way around) and more fulfilling lives. To a scientist, technology is the end product of one's research. To an engineer, technology is a tool or process that can be employed to build better products or solve technical problems. To an attorney, technology is intellectual property to be protected and guarded. To a business executive, technology may be the most important, yet least understood, company asset. Technology is viewed as competitive advantage against rivals.

Technology means state power to both developing and developed countries. Technology is regarded as a strategic instrument in achieving economic targets and in the creation of wealth and prosperity in the developing countries, while technology is taken as an important vehicle to get large profits in the developed countries. The effective use of technology is perhaps the most important issue faced by both developing and developed countries, and will undoubtedly become even more critical in years to come.

The word "technology" usually conjures up many different images and generally refers to what has been described as the "high-tech," or high-technology, industries. It has to be understood that limiting technology to high-tech industries such as computers, superconductivity, chips, genetic engineering, robotics, magnetic railways and so on focuses excessive attention on what the media consider newsworthy (Gaynor 1996). However, limiting technology to science, engineering and mathematics also loses sight of other supporting technologies. Actually, technology includes more than machines, processes and inventions. Traditionally, it might concentrate more on hardware; however, in these days, more on soft side as well. There are many manifestations of technology; some are very simple, while others are very complex.

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What Is Technology?

But what exactly is meant by the term "technology"? According to Dean and LeMaster (1995, p. 19), technology is defined as "firm-specific information concerning characteristics and performance properties of production processes and product design." While Contractor and Sagafi-Nejad (1981) describe technology simply as "a bundle of information, rights and services," Maskus (2004, p. 9) defines technology as "the information necessary to achieve a certain production outcome from a particular mean of combining or processing selected inputs." However, Maskus (2004) solely distinguishes between embodied and disembodied technology, whereas Kedia and Bhagat (1988) recommend a more detailed classification into process-, product- and person-embodied technology.

Technology represents the combination of human understanding of natural laws and phenomena accumulated since ancient times to make things that fulfill our needs and desires or that perform certain functions (Karatsu 1990). In other words, technology has to create things that benefit human beings. Miles (1995) defines technology as the means by which we apply our understanding of the natural world to the solution of practical problems. It is a combination of "hardware" (buildings, plant and equipment) and "software" (skills, knowledge, experience, together with suitable organizational and institutional arrangement).

The UN Conference on Trade and Development (UNCTAD) has provided the following definition:

> Technology is bought and sold as capital goods including machinery and productive systems, human labour usually skilled manpower, management and specialised scientists. Information of both technical and commercial character, including that which is readily available, and that subject to proprietary rights and restrictions.

However, according to this thesis, technology cannot merely be considered as a production factor, and it is not socially neutral (Mnaas 1990). It seems much easier for understanding "technology" to consider the concept of "technology" as consisting of four closely interlinked elements: namely, technique, knowledge (normally being considered as "technology"), the organization of the production, and the product. However, knowledge does not make sense if the organization of the relevant production goes without producing meaningful product. Therefore, technology must be applied, testified and maintained, which implies a demand for a further input of a suitable range of human resources and skills. However, it should be noticed that it is this latter input that is at the root of the difficulty in transferring technologies between different environments. Nevertheless the modern view emphasizes the coherence of technology and knowledge, and points out that technology transfer is not achievable without knowledge transfer as knowledge is a key to controlling technology as a whole (Li-Hua 2004); some even use "technology" interchangeably with "know-how." Knowledge is closely related to technology since the pure disposal of technology is not sufficient for a successful implementation. In the majority of the cases, especially in complex technology, knowledge, in particular tacit knowledge, is required for a successful international technology transfer.

Technique covers the instruments of labor (machinery and tools), materials and the way they are brought into function by labor in the working process. Both social dynamic (working process) and social contradictions (e.g. between machinery and labor) are inherent in this element of the technology as in each of the subconcepts.

Knowledge consists of three principal categories: applied science, skills and intuition. The weighting between these categories of knowledge is changing historically, but in every case an adequate combination of types of knowledge must be present. *Knowledge is the "key to control" over technology as a whole*, which can be seen both at micro-level (Taylorism) and at higher levels of social aggregation (technological dependency) (Mnaas 1990). However, it is helpful for understanding that knowledge has recently been classified as explicit knowledge and tacit knowledge.

Technique and knowledge must be organized before they can bring about effective results. Organization is therefore an integral part of technology. Organization of a working process of technique and knowledge into a product may have technical causes, but mostly the actual choice of organization will rest widely on social-economic causes and reflect the general social structure of society.

Product. The ultimate purpose of bringing technique, knowledge and organization together is of course to obtain a product. Without including this goal, it is in fact difficult to understand the other three elements properly. It seems natural to include the product in a comprehensive technology concept, not least because in practice the choice of product often precedes the choice of the technique, knowledge and organization by which it is going to be produced.

Rosenberg and Frischtak (1985) pointed out that the specificity of technology has close links with the nature of the inputs to its production and of the resulting outputs. In most advanced countries, at least 60 percent of research and development expenditures are on development, namely expenditure to develop specific products or production processes. It is important to have this dissecting of technology and to have a distinction between technology and knowledge. Knowledge is a fluid mix of framed experience, values, contextual information and expert insight that provides a framework for evaluating and incorporating new experiences and information. It consists of truth, beliefs, perspectives, concepts, judgments, expectation, methodologies, know-how; and exists in different forms such as tacit, explicit, symbolic, embodied, en-brained and en-cultured knowledge.

Explicit Knowledge and Tacit Knowledge

Knowledge is increasingly being recognized as a vital organizational resource that gives market leverage and competitive advantage (Nonaka and Takeuchi 1995; Leonard-Barton 1995). In particular, knowledge has become a substance to be "managed" in its most literal sense. Polanyi (1967) considered human knowledge by starting from the fact that *we know more than we can tell*. In general, knowledge consists of two components, namely explicit and tacit. Technical knowledge consists of these two components, "explicit" and "tacit"; however, the greater the extent to which a technology exists in the form of the softer, less physical resources, the greater the proportion of tacit knowledge it contains. Tacit knowledge, owing to its non-codifiable nature, has to be transferred through

Table 2.1 Features of tacit knowledge and explicit knowledge (Nonaka and Takeuchi, 1995)

Tacit knowledge *Subjective*	*Explicit knowledge* *Objective*
Knowledge of experience (body)	Knowledge of rationality (mind)
Simultaneous knowledge (here and now)	Sequential knowledge (there and then)
Analogy knowledge (practice)	Digital knowledge (theory)

"intimate human interactions" (Tsang 1997). In the meantime, it has to be recognized that tacit knowledge is the key to delivering the most competitive advantage, and it is this part that competitors have difficulties in replicating. Tacit knowledge transfer is often intentionally blocked because people understand the significance of tacit knowledge.

Nonaka and Takeuchi (1995) describe some distinctions between tacit and explicit knowledge, which are shown in Table 2.1. Features generally associated with the more tacit aspects of knowledge are shown on the left, while the corresponding qualities related to explicit knowledge are shown on the right. Knowledge of experience tends to be tacit, physical and subjective, while knowledge of rationality tends to be explicit, metaphysical and objective. Tacit knowledge is created "here and now" in a specific, practical context, while explicit knowledge is about past events or objects "there and then." Table 2.1 shows the features of explicit and tacit knowledge.

Having clarified the distinctive features between technology and knowledge, and between explicit knowledge and tacit knowledge, it is now more helpful in this discussion to reflex the current debate on why China's technology strategy of getting technology by giving up its market partly failed. In the last twenty-eight years of economic reform, China has achieved tremendous success and seen the most remarkable period of economic growth in modern times, and will continue to do so. However, the debate is going on that the foreign brands sell well in the Chinese market and foreign companies are strong competitors against local firms, and to some extent China has not really obtained core technology in the car manufacturing industry. It has to be recognized that this thesis is not in a position to provide appropriate answers to these questions. However, bearing in mind that knowledge is a key to controlling technology as a whole, technology transfer does not take place without knowledge transfer. In terms of technology import or technology transfer, what China has obtained in principle is the "hard" ware, such as machinery, equipment, operational manual, specification and drawing, – not the "soft" side, which consists of tacit knowledge, including management expertise and technical know-how and know-why.

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8

Technology and Science

DON IHDE

The term *technoscience* has come into vogue in the last two decades. It suggests a sort of hybrid combining of technology and science, and has been used by many of the best-known Science and Technology Studies writers ranging from Bruno Latour to Donna Haraway and others. Such a hybridization stands in contrast to an older usage which suggested not only distinct differences between science and technology, but also a clear relation of dependence of technology upon science, as in the once popular usage of "applied science" referring to most engineering in its modern sense. This usage prevailed well into the twentieth century and still exists as a title for some programs, but has increasingly been called into question.

Are we undergoing a major shift in the terms of the once *master narrative* which both characterized and distinguished technology and science? Paul Forman, intellectual historian and curator of Medicine and Science at the Smithsonian Institution, thinks so. In a recent special issue of *History and Technology* (vol. 23, 2007), he argued that intellectually there was a "primacy of science in modernity" and that this shifted to a primacy of "technology in postmodernity," but that this shift was not recognized until recently by historians owing to their own ideology. Part of Forman's thesis is that the watershed for the shift was roughly 1980, and with a historian's scrupulous footnoting – 424 of them! – he shows how, in modernity, it was presumed that science was the primary source of ideas, theories and practices which both defined it as "prior" to technology and also distinct from it.

The shift, of course, began to be glimpsed well before 1980; and Forman recognizes, for example, the prescient role played by Martin Heidegger in the mid-twentieth century. Heidegger's famous "The Question Concerning Technology" (1954) raises the question about the *ontological priority of technology over science.* In his convoluted way, Heidegger claimed:

> Chronologically speaking, modern physical science begins in the seventeenth century. In contrast, machine-power technology develops only in the second half of the eighteenth century. But modern technology, which for chronological reckoning is the later, is, from the point of view of the essence holding sway within it, the historically earlier.
>
> (1977: 23)

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And Heidegger early on also points out that science itself uses and is dependent upon technologies:

> It is said that modern technology is something incomparably different from all early technologies because it is based on modern physics as an exact science. Meanwhile, we have come to see that the reverse holds true as well: Modern physics, as experimental, is dependent upon technical apparatus and upon the progress in building technological apparatus.
>
> (1977: 14)

While in some sense Heidegger is prescient concerning technoscience, in another – in his view that there is a sharp disjunction between modern and pre-modern technologies – he remains under the perspective of the primacy of science in modernity.

Clearly, in anthropological–historical terms, technologies as used by humans *predate modern humans (Homo sapiens)* since even our premodern ancestors used technologies for more than a million years prior to our own evolutionary emergence. But what of science? If the modernist master narrative is to be believed, this would make science much "later" than technology in a different sense. The modernist narrative places science, as with Heidegger, in the seventeenth century and, additionally, originating largely in a Western or European context in the Eurocentric narrative. But a Eurocentric interpretation of science is equally an invention of modernity and, as with the primacy of science over technology, is today under severe criticism. Its Eurocentrism, however, was not always taken for granted even in our own history. As early as the beginning of the seventeenth century, Francis Bacon claimed that the inventions which most benefited progress, and thus modernity, were paper-making, gunpowder, the magnetic compass and the movable-type printing press. But he also recognized that the inventors were the *Chinese*, who "completely changed the world's appearance . . . and displayed [the biggest] influence upon human progress" (1623). Thus, at the beginning of early modernity, what later became thought to be dominantly a Western and European science was not. Joseph Needham, much later, continued to chronicle Chinese technology, but he also claimed that this inventiveness died out and did not develop into the Western, theoretical science which became the ideal of late modernity.

If Forman is right, then the inversion of primacy – science with modernity and technology with postmodernity – poses a set of questions which arise with respect to technology and science and which begin to take different shapes contemporarily. One set of agreements would now seem to hold: the sciences are *instrumentally embodied.* But they are so embodied in different ways in the different sciences. While the positivist program earlier in the twentieth century included a hope for a unified science, ultimately related back to physics as foundational, it is clear in a postmodern era that such a program no longer is possible. Different sciences exhibit different science cultures and practices. For example, in astronomy, observation – until what is today called the *new astronomy* – had always been limited to what could be seen within the limits of optical light. Indeed, until early modernity the limits to optical light were also limits of what humans could themselves see within their limited and relative perceptual spectrum of human vision. With early modernity and the invention of lensed optical instruments – telescopes – astronomers could begin to observe phenomena never seen before.

Magnification and resolution began to allow what was previously imperceptible to be perceived – but within the familiar limits of optical vision. Galileo, having learned of the Dutch invention of a telescope by Hans Lippershey, went on to build some hundred of his own, improving from the Dutch 3x to nearly 30x telescopes – which turn out to be the limit of magnificational power without chromatic distortion. And it was with his own telescopes that he made the observations launching early modern astronomy (phases of Venus, satellites of Jupiter, etc.). Isaac Newton's later improvement with reflecting telescopes expanded upon the magnificational-resolution capacity of optical observation; and, from Newton to the twentieth century, improvement continued on to the later very large array of light telescopes today – following the usual technological trajectory of "more-is-better" but still remaining within the limits of the light spectrum. Today's astronomy has now had the benefit of some four centuries of optical telescopy. The "new astronomy," however, opens the full known electromagnetic spectrum to observation, beginning with the accidental discovery of radio astronomy early in the twentieth century, and leading today to the diverse variety of EMS telescopes which can explore the range from gamma to radio waves. Thus, astronomy, now outfitted with new instruments, "smart" adaptive optics, very large arrays, etc., illustrates one style of instrumentally embodied science – a technoscience. Of course astronomy, with the very recent exceptions of probes to solar system bodies (Moon, Mars, Venus, asteroids), remains largely a "receptive" science, dependent upon instrumentation which can detect and receive emissions.

Contemporary biology displays a quite different instrument array and, according to Evelyn Fox-Keller, also a different scientific culture. She cites her own experience, coming from mathematical physics into microbiology, and takes account of the distinctive instrumental culture in her *Making Sense of Life* (2002). Here, particularly with the development of biotechnology, instrumentation is far more *interventional* than in the astronomy case. Microscopic instrumentation can be and often is interventional in style: "gene-splicing" and other techniques of biotechnology, while still in their infancy, are clearly part of the interventional trajectory of biological instrumentation. Yet, in both disciplines, the sciences involved are today highly instrumentalized and could not progress successfully without constant improvements upon the respective instrumental trajectories. So, minimalistically, one may conclude that the sciences are *technologically, instrumentally embodied.* But the styles of embodiment differ, and perhaps the last of the scientific disciplines to move into such technical embodiment is mathematics, which only contemporarily has come to rely more and more upon the computational machinery now in common use. Isabel Stengers has seen, perhaps more clearly than many, the imaginative possibilities of such an instrumentally embodied mathematics, hinted at in her *The Invention of Modern Science* (2000). She glimpses the new styles of analysis which become possible through computer simulation, modeling and tomographical processes which are only now coming into preliminary maturity.

In a broad sense, of course, historians, anthropologists and archeologists have always known that technologies are "older" than science *if science is conceived of as it was by the modernist notion of science propagated by modern philosophy of science.* The Stone Age tool kit goes all the way back to *Homo erectus* and beyond. But other soft technologies, such as nets, fiber, bamboo and wood, also must go back into the prehistoric–premodern human. Wooden spear-shafts dated 400,000 BP have occasionally been discovered, but such discoveries are rare compared to Acheulean hand axes of 1,000,000+ BP. The historical commonplace, "Science owes more to the steam engine than the steam engine to science," which points to the historical fact that the questions which led to the discovery of the laws of thermodynamics came from questions of energy loss in early steam engines, not from observations of nature, is part of this pre-Forman shift to post-modernity's primacy of technology over science.

So how and why did modernity hold so tenaciously to the primacy of science? Part of the answer relates to the question: Who *interprets* science? And with respect to the twentieth century it is arguably the case that *philosophers of science* tended to prevail. Here several generalizations do seem to hold up: first, the paradigm or dominant science forefronted by philosophers of science in the twentieth century was *physics* – particularly mathematical physics – and its nearest relations. Earlier, one could argue that astronomy and cosmology occupied much of early modernity's interpretation, but even here the caveat is that the central interest of philosophers of science remained the laws of motion and their generalization into universality, thus, physics. The giants of early-twentieth-century philosophy of science were Pierre Duhem, Jules Henri Poincaré and Ernst Mach, all themselves mathematician-philosophers and all decreeing the mathematical "essence" of physics. Thus, the image of science which emerged from this set of interpreters was a science which was *ahistorical, acultural, "mathematical" or theoretical* and *context-free.* By the time of positivism and logical empiricism, most of that image of science was retained as was the centrality of theory-bias, although one could add a weighting to logical and propositional focii to the earlier mathematization emphasis, along with concerns with observation for verification purposes. Programs such as the unification of science and the proliferation of positivist philosophy of science in the universities are well-recognized parts of this part of the history of the philosophy of science to the mid-twentieth century. Rudolph Carnap, Hans Reichenbach, Herbert Feigl, Carl Hempel, Moritz Schlick et al. were some of these familiar names.

By mid-century, objections began to counter the positivist programs, and what today is usually called the "positivist-anti-positivist wars" began. Karl Popper, Imre Lakotos, Paul Feyerabend and pre-eminently Thomas Kuhn were the anti-positivist critics. And, although concrete *histories*, *instruments* and, to some degree, *experiments* begin to play a role in science interpretation, it was not until later in the twentieth century that a shift to a *praxis*, *laboratory* and new *experimental* focus began to overwhelm the earlier trajectory of theory-centered interpretation. Before leaving philosophers of science as key interpreters of science, the appearance in the 1980s, precisely after Forman's watershed year, of experiment- and instrument-oriented philosophy of science began to make inroads. Ian Hacking's *Representing and Intervening* (1983), with its marked shift to intervention and manipulation via experiment and instruments, was one landmark. Robert Ackermann followed with *Data, Instruments and Theory* (1985), and Peter Galison with *How Experiments End* (1987).

To this point, interpreters of science from the philosophy of science have been noted; but, even before the new experiment- and instrument-sensitive philosophy of science gained momentum, new challengers for interpretations of science which were *practice*-oriented and focused upon experiments, instruments and laboratories were under way. This was especially marked by the new and largely "post-Mertonian" sociologies of science from both the United Kingdom and Europe. "Social Constructionism," "The Strong Programme" and "Actor Network Theory" by the mid-1980s were in strong contention with interpretations of science which looked at the social and sometimes material cultures of science. Here the names of Trevor Pinch, Harry Collins, Steve Woolgar, Michel Callon, Bruno Latour, Karin Knorr-Cetina began to appear. Philosophers of science had new interpretive competition, and the "wars" which occurred were an indirect recognition of the contention.

What of the philosophy of *technology*? For the most part, one can say that the philosophy of technology is primarily a twentieth-century development. While, at the end of the nineteenth century, the two neo-Hegelians, Ernst Kapp and Karl Marx, both turned "idealism" upside down and began to look at technologies and productive processes as leading to, or even determining, societal outputs, it was only after the strongest effects of the Industrial Revolution and the emergence of militarized technologies from the two world wars that major philosophers looked deeply and seriously into technology. With the exception of John Dewey on the American scene, most early philosophy of technology was European, and mostly deriving from what could be called the more *praxis*-oriented traditions such as Marxian, phenomenological, and including American pragmatism. Looking back over the last century, there is now close to a consensus regarding the beginnings of the philosophy of technology. Publications range from Carl Mitcham's well-recognized history of the philosophy of technology, *Thinking through Technology: The Path between Engineering and Philosophy* (1994), to the work of the Twente group of philosophers of technology under the leadership of Hans Achterhuis with *De Maat van de techniek* (1992) and *Van Stoommachine tot Cyborg: denken over techniek in de nieuwe wereld* (1997), later translated with updates into *American Philosophy of Technology: The Empirical Turn* (2001). Following Achterhuis, one could characterize early-twentieth-century philosophy of technology as concerned with technology-in-general at a "transcendental" level; as often dystopian in tone; and as portending an end to the modern era. Friedrich Dessauer, a neo-Kantian, and Martin Heidegger both addressed technological themes as early as 1927; but Ortega y Gasset, Karl Jaspers, many of the principals of the Frankfurt School, including Adorno, Herbert Marcuse and Jürgen Habermas, also began to write about technological themes. In contrast to these early-to-mid-twentieth-century thinkers, in the later twentieth century a second generation of philosophers of technology were seen as taking an "empirical turn" to the closer-up examination of a plurality of particular technologies, as more pragmatic in outlook; and as democratic in aim. Achterhuis's *American Philosophy of Technology* includes introductions to Albert Borgmann, Hubert Dreyfus, Andrew Feenberg, Donna Haraway, Don Ihde and Langdon Winner as those who are located under the new descriptions. With respect to technologies and science, I will mention my *Instrumental Realism: The Interface between Philosophy of Science and Philosophy of Technology* (1991), which addresses a wide spectrum of both philosophers of science and philosophers of technology with emphasis upon science's technologies. And my earlier *Technics and Praxis: A Philosophy of Technology* (1979) had already argued that science has all along been technologically embodied.

Thus, from an enlarging field of differently based interpreters, the roles of technology vis-à-vis science have become more visible from the late twentieth century into the twenty-first. In this section of the *Companion to the Philosophy of Technology*, the contributors to the themes of technology and science again also actually display a variety of opinions, clearly calling into question any "standard view" of the primacy of science over technology, but not often going so far as to invert the relationship to a "Heideggerian" one of the primacy of technology over science, nor to the hybridization of technology and science into a technoscience.

Three of the contributing philosophers – incidentally all from the Netherlands – all recognize the contemporary shift which has occurred in philosophies of science. Hans Radder notes that, from the earlier, one could say more elitist perspectives of "scientism" and "technocracy," current shifts towards "methological naturalism" and "critical normativity" are also more concrete and, one could say, empirical, with respect to the earlier and more ideological tones of the last century. Bart Gremmen claims that the science–technology relationship to the seventies was dominated, again, by the theory concerns of philosophy of science, thus confirming the modernist frame suggested by Forman as well. Gremmen, however, sees something like an interaction schema replacing the modernist one, in which there remains a certain distinction between technology and science and the interrelation of the cognate philosophies thereof. And Mieke Boon, quite aware of the emergence of the notion of technoscience, sees the shift centering on emphases on a "new experimentalism" related both to philosophy of science and philosophy of technology, but also relates this to a movement toward recognizing a unique style of *technological knowledge*. In all three cases, the older traditions of a strong distinction between *episteme* and *techne* are called into question.

Indeed, the largest group of contributors to this section could be characterized as interested precisely in forms of "technological knowledge." Anthonie Meijers and Marc de Vries make technological knowledge their primary theme, arguing against now dated notions of "applied science" and for a distinct and recognizable *technological* knowledge. Peter Kroes argues, in a parallel vein, that, in so far as engineering and design must take into account human needs, actions and values there can be something like a history of intentionality which plays into the human–technical juncture. Somewhat more extreme, Wiebe Bijker, one of the principals in the social construction of technology movement, shows a wide spectrum of social–cultural aspects which permeate technologies, drawing from some of his past work on specific technological developments. Louis Bucciarelli, while allowing as a background phenomenon the older notions of science, forefronts the notion of an *engineering science,* again having its own validity as a type of knowledge. Along with Kroes and Meijers and de Vries, function plays a strong role. Keekok Lee plays a similar role in the critique of the ancient *episteme/techne* distinction when dealing with technology and biology. The very notion of a biotechnology and its manipulations and constructions of new biological entities belies such ancient distinctions. Finally, in some respects coming the closest to an inversion of the modernist primacy-of-science notion, are the essays of Helge Kragh, W. J. Nuttall and Andrew Pickering. All hold, in different contexts and for different sciences, variants upon how new technologies or discoveries in technologies not only impact upon science, but also effectively invent to stimulate new sciences. Kragh does this historically with respect to chemistry: the discoveries of phosphorus, soda and sulfuric acid were all made either accidentally or serendipitously and led to one of the first "Big Sciences" in chemistry, without benefit of theoretical science which only later could deal with the atomic and molecular theory needed to have such a chemical science. Nuttall, by tracing aspects of nuclear science and the development of nuclear weaponry, shows how, once again, a set of technologies carries enormous implications for the practices, politics and formation of science – in this case Cold War physics and engineering. Pickering, again drawing from developments in the same era, takes cybernetics as yet another "technological" development which leads to a new type of science, one still under development in a number of science disciplines. These entries, not unlike that of the steam-engine-to-thermodynamics maxim cited above, come the closest to the primacy of technology over science in a postmodern sense. And in all cases it is clear that a modernist consensus regarding the sheer primacy of science over technology no longer holds for most contemporary thinkers. And it should equally be clear that the "thin" and theory-biased image of science, often narrowly concerned with physics, has equally been called into question. A more complicated image of science, in some ways actually looking more like a technologically practiced science, has emerged. Such a science is, or has, cultural, historical, contextual, social–political features – and is, as Larry Laudan proclaims for all contemporary philosophy of science – fallibilistic.

If the ground has shifted, particularly with respect to modernism, and, if the criticisms of modernism need to take into account cultures, histories, technologies, what would a *technoscience interpretation* of the relations between technology and science look like? Here, rather than take the direction taken by Forman concerning the "primacy of technology," this reframing will examine a more symbiotic technology/science direction, one suggested by the term "technoscience." This, too, would be a reframing of the question, but one which reflects some aspects of a more *pragmatist* interpretation. Such a reframing would hold that (*a*) the style of robust, repeatable and dependable knowledge which we identify with science *has always been a process which entails technologies*; (*b*) since it is a human activity which responds to needs for knowledge in a variety of contexts, it should be identifiable wherever and whenever it has occurred; and (*c*) it can also be variously contexted, relative to the needs and shapes of the societies into which such practices fit. This reframing, as will be shown, ends up being multicultural, occurring in many different places and times, and is developmental, particularly with respect to the refinement and progression of the technologies used in producing the knowledge entailed.

Once again, this reframing narrative begins with the very ancient science – astronomy. Even our prehistoric ancestors observed the celestial motions of the night-time skies and very early on began to develop *calendars*, which are one form of "writing" technology which can make repeatable patterns available, including passing on a record for later generations to recognize. Moon phases have been found marked on reindeer antlers, counting-sticks and the like, going back at least as far as the Ice Age images of 30,000+ BP. The full lunar and solar calendars, some more accurate than those of the European Middle Ages, can be found in a number of ancient civilizations stretching from the Middle East to Meso-America. And the writing technology of the calendar-artifact is, as contemporary archeoastronomy has now shown, not the only technology relevant to the ancients. *Observational instruments* also played an apparent role. It has long been surmised that Stonehenge (4500 BP) was used as an observational instrument; and, as Anthony Aveni and Dick Teresi have pointed out, similar stone rings, sighting tunnels and the like have been found aligned with ancient observations in many areas of the globe. In fact, some are so ancient that only by taking into account the shift in precession changes in celestial alignment can dating of prime usage time be established (Amerindian rings have been dated for such usage at least 3000 BP). The point here is simple: observations of this sort have been made in many cultures, in great antiquity, and were both recorded on various forms of writing technologies and observed by means of simple instruments. Is this, then, ancient technoscience? If so, it has plural origins, but can also accommodate our own standard history, which also includes significant discoveries. Robert Crease's *The Prism and the Pendulum* (2006) is a monograph responding to a physics educators' poll concerning the ten most beautiful experiments in science history. The most cited example was from Hellenic Greek times, that of Eratosthenes' measurement of the circumference of the earth. By using a gnomon, a stick sundial which at the summer solstice cast no shadow, combined with relatively simple geometry with a known distance between two cities – one the observation site, the second where the angle of shadow could be measured – through simple triangulation he was able to produce a respectable measurement of the earth's circumference. This, too, is an instrumental-styled, mathematically interpreted technoscience, this time within our standard master narrative theme.

The reframing being suggested here takes account of both multicultural instances of science, better technoscience, and of its embeddedness in both a material culture and material instrumentalization. And, while few recent authors have ventured into the multicultural aspect of this territory, some have made significant gestures in this direction, including: Sandra Harding with *Is Science Multicultural?* (1998); Dick Teresi, *Lost Discoveries: Ancient Roots of Modern Science* (2002); Helaine Selin's massive *Encyclopedia of the History of Science, Technology and Medicine in Non-Western Cultures* (1997). Such studies only now begin to expand and supplement the older traditions – such as those of Bacon to Needham mentioned above – which recognize only limited non-Western technoscience origins such as China. What emerges is a different, more scattered, but also more understandable profile of scientific and technological inventions and discoveries. For example, and again only due to contemporary dating techniques, it is beginning to be understood that grain domestication occurred in many different places of the earth roughly between 8000 and – 10,000 BP, in the Middle East, in Asia, and even in Meso-America – and with different grain combinations, usually a dominant grain or a few dominant grains, with most grains not undergoing selection for hypertrophism. Thus, wheat, rice and corn respectively fit into the samples above; but other examples, too, have begun to be recognized (figs, squash and beans, and the like). Granted, there is a kind of irony with both why and how such a reframing can take place in postmodernity. The irony is that only contemporarily do we have the instrumentation to determine with accuracy the dating, the identification of the materials involved and thus the recognition of past, often previously lost practices. This same inventiveness, the multiculturalists have begun to recognize, can also occur in much more abstract activities. Teresi points out, along with others such as Robert and Elaine Kaplan, that "zero" has been invented a number of times in a number of ancient cultures. The Babylonians may have been first with zero as a place-holder 3800 BP, but later with a genuine zero, 3100 BP; but Hindu culture also invented zero, and, from these sources in Asia and the Middle East, Arabic culture borrowed and then conveyed the notion of zero into a reluctant and late European culture which, only on accepting Arabic number concepts, incorporated zero into its own system. And, although very separate from the Old World cultures mentioned, the Mayans also independently invented zero. Thus, once again, one must call into question the monodimensionality of the older master narrative so much taken for granted in Eurocentric histories. The antiquity of writing is another multi-origin example: cuneiform writing continues to hold its place from at least 6000 BP in the Old World history, but twentieth-century finds of tortoise-shell writing from China now also equal a 6000 BP dated origin. Here, then, a pragmatist human-inventivity model for the production of tools again allows for the recognition of such a pluralistic set of histories.

Admittedly, much of the ancient knowledge now re-emerging had disappeared. There does not seem to be anything like a single continuous history of sciences any more than there is a continuous history of "civilization" as such. But, within these plural histories, there are also telling examples of how technologically progressive trajectories lead both to refinements of knowledge and to breakthroughs. As noted, astronomy underwent a many-millennia period limited to human visual observation in relation to simple, fixed observational instruments. Lenses qualitatively changed the range and type of observation possible and allowed for the four-century history familiar to the Eurocentric account. Interestingly, sunspots and their periodicity was first noted by Galileo in the early seventeenth century with the aid of a telescope of his own design, and which included a helioscope to cast sunspot images on a screen. In China, however, sunspot activity had been noted and charted since 2500 BP by Gan De, Shi Shen and others. Without telescopes, how could these phenomena be observed? While the answer is not definitive, one can note that very early lens development in China included the use of dark quartz, which could have been used for precisely such sightings. Yet, in spite of the earlier charting of sunspot activity in China and the later charting in early modernity, the discovery of the eleven-year sunspot cycle and its relation to auroral activity had to await later modernity in spite of the fact that the charts from antiquity evidence this pattern. The point being made is that technologies, instrumentation, mediate and make possible different and refined observations. And, in one sense, this becomes even more pronounced in late modernity, as Peter Galison has pointed out in *Einstein's Clocks, Poincaré's Maps: Empires of Time* (2003). The history and discovery of special relativity and its relationship to time relates to the more accurate time-keeping which became possible only in the twentieth century. Until clocks were both accurate enough to measure micro-seconds, and put into synchonized systems – such as the various proposals for a universal time to govern railway traffic which patents Albert Einstein dealt with in his 1905 career – could the clearer implications of relativistic time be more deeply probed. Galison shows how this technological lifeworld is the concrete context within which relativity is conceived.

Thus, the framing being suggested here, in both its pragmatist sense which emphasizes human inventiveness in its material dimension including technologies, and in a phenomenological sense in which human perception and embodiment plays a role, can more fully accommodate a technoscience, or hybridized technologies and sciences in what can be understood as both symbiotic in relationship and multicultural in origin and pluralistic in both temporal and geographic localities can here come into view.

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9

Science and Technology: Positivism and Critique

HANS RADDER

The notion of positivism, which is primarily used in relation to science, is notoriously ambiguous. Karl Popper, for one, strongly argued against positivist philosophy of science *and* was sharply criticized for being a positivist philosopher of science himself. In epistemology, positivism is often seen as equivalent to empiricism; in philosophy of science, it usually means "anti-realism"; in methodological discourse, it frequently refers to a unity-of-science approach according to which the social sciences should follow the methodology of the natural sciences; in social science, it commonly stands for a preference of quantitative over qualitative methods; and in ontological debates it may denote reductionist or materialist positions.

Clearly, some limitation and clarification is in order, the more so since not all of these senses of positivism will be equally relevant to both science and technology. For the purpose of this essay, I start with the influential views of (the early) Jürgen Habermas, who conceived of science and technology as being intrinsically related. Habermas proposes a very broad characterization of positivism as the view that, because of their obvious successes, there is no need for a critical reflection on science and technology "as such." The latter qualification is important, since positivism acknowledges, and even explicitly aims to criticize, the occurrence of particular deviations from scientific or technological rationality.

In addition to this, positivism often includes a stronger normative view, saying that a scientific or a technological approach is the best, or even the only legitimate, approach to tackle any economic, socio-cultural or personal problem. Put differently, positivism equates knowledge with science and accordingly claims that only science and science-based technology can bring us material and social progress. In the case of science, this approach is called scientism; in the case of technology, one speaks of technocracy. Such views are still quite current (though not unchallenged) among scientists, technologists, policy-makers, politicians and the general public. For instance, a scientistic approach to human intelligence holds that intelligence is what IQ tests measure, and a technocratic policy proceeds by replacing culturally specific actors' notions of intelligence with scientific practices, such as testing children at school and adults during application procedures. Or, in the face of the threatening exhaustion of fossil fuels, technocracy advocates a technological fix through a strong expansion of nuclear power (despite its many unsolved problems), while legitimate concerns are being silenced through

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the scientistic strategy of distinguishing between the objective risk revealed by the scientific experts and the merely perceived (and hence subjective and unreal) risk of the lay critics.

In his *Knowledge and Human Interests*, Habermas (1978) criticizes Auguste Comte's and Ernst Mach's positivist views of science for being unreflexive. They focus on methodological and epistemological issues, such as the function of scientific experience and the nature of scientific theories. In doing so, they forgo the reflexive Kantian question of the general conditions of the possibility of scientific knowledge. As already mentioned, Habermas sees this "disavowal of reflection" as the core problem of positivism. Positivism unjustly takes the factual successes of the scientific approach to be enough epistemic justification and social legitimation. Against this, Habermas first points to the significance of human, instrumental or experimental action as the condition of the possibility of scientific knowledge; second, he claims that critical reflection on science should take full account of communicative action, which is the condition of the possibility of the interpretive humanities and, more generally, of mutual understanding in our life-world. That is to say, the sphere of communicative action constitutes a more basic outside "position" from which the development of science may be critically questioned. Thus, Habermas' critique of positivism in science results in assigning science its proper place, relative to the interpretive disciplines and to our life-world. Science is a legitimate human endeavor, but it is also one-sided, and hence its unconstrained expansion should be counteracted from the sphere of communicative action.

Something similar applies to technology since, according to Habermas, science is intrinsically related to technology, with experimentation being the crucial link. Both science and technology aim at prediction and control of the events studied theoretically and realized experimentally or technologically. Technology has its proper place as an instrumental means for supporting the survival of individual human beings and of human kind more generally. All too often, however, technology intrudes on, and intends to replace, communicative discourse and action concerning societal goals (see Habermas 1971). Positivism provides an ideological underpinning of this improper "colonization of the life-world," since it claims that the actual practices of science and technology need not, and should not, be normatively constrained from an independent domain of communicative action.

It is along these lines that Habermas analyzes and criticizes the scientistic and technocratic doctrines of positivism. Yet one may argue that Habermas' approach still includes a positivist residue: because of his claim that the validity of scientific facts and the effectiveness of technological artifacts are independent of *particular* societal interests and *specific* norms and values, his account of the conditions of the possibility of science and technology is inadequate. Science and technology are seen as yielding universally valid knowledge and objectively working tools that are normatively neutral and acquire value only when applied for specific social purposes. Thus, laser science and technology as such provide neutral knowledge and effective tools, which only become value- and interest-laden when used, for instance for healing or for killing people.

More recent studies of scientific practice, however, have claimed that scientific knowledge is never neutral and universally valid, but socially constructed on the basis of particular social goals and interests or as a result of specific processes of social negotiation (see Barnes, Bloor and Henry 1996). Thus, the new experimental procedures advocated by Robert Boyle and the dispute about those procedures between Boyle and Thomas Hobbes are claimed to depend crucially on a local aspect of the seventeenth-century English social order. In technology, the "validity" – that is, the objectivity and effectiveness – of technological artifacts and systems has similarly been claimed to be socially constructed through negotiation among involved actors or through powerful individual and institutional system-builders (Bijker, Hughes and Pinch 1987). Illustrations are the development of the bicycle in the last decades of the nineteenth century and the evolution of the system of electric light and power in Western societies between 1870 and 1940. At present, such detailed studies of scientific and technological practice abound. They have been framed into a comprehensive (social) constructivist research tradition. This tradition may be characterized as broadly naturalistic: it focuses on accurate empirical description and explanation of actual scientific or technological practices with the help of (social) scientific methods.

Thus, from a (social) constructivist perspective, Habermas himself is still a captive of positivism in that he endorses its untenable doctrines of the universality and neutrality of science and technology. One reason for holding these mistaken views is the abstract nature of Habermas' theorizing, which does not include any illustrations from science or technology, let alone extensive studies of actual scientific or technological practices. But how does (social) constructivism itself relate to positivism? In terms of Habermas' characterization, constructivist reflection has explored in great detail not only the general but especially the particular conditions of the possibility of science and technology. More specifically, constructivism has emphasized the methodological and epistemological disunity and the ontological multiplicity of the sciences (see Mol 2002). Furthermore, in their explicit declarations, constructivists do not endorse the strongly normative claims of scientism and technocracy. For these reasons, the constructivist tradition might be classified as anti-positivist.

Yet one important element of Habermas' anti-positivism is missing from this tradition. Habermas advocated not mere reflection on the conditions of possibility of science and technology, but *critical* reflection in the sense of including a normative critique of the roles of science and technology in our present society. In contrast, many naturalistic studies of science and technology claim to provide no more than an impartial description or explanation of scientific and technological practices, and quite a few argue strongly against taking a normative stance on the scientific and technological issues they study.[1] Put differently, while constructivists have rightly questioned the rigid contrast between science and society, made by both the positivists and Habermas, they have wrongly concluded that this also entails the dissolution of the notion and possibility of critical normativity. The latter, however, is a non sequitur (see Winner 1993; Radder 1996, chs 5 and 8).

Consider, for instance, Habermas' emphasis on the importance of the notions of technological prediction and control. These notions may be reinterpreted as being *theoretically* necessary for successfully realizing a stable and reproducible technology (see Radder 1996, chs 6 and 7). Of course, it remains a matter of empirical study to see whether or not this success has materialized in actual practice. None the less, the *attempt* at realizing stable and reproducible technologies may be critically assessed for two reasons. A first question is whether the required material and social control needed for successfully realizing a stable and reproducible technology can be reasonably expected to be feasible. If not, we should refrain from realizing this specific technology. But, second, even if this material and social control can be successfully realized, the normative question should be asked whether living in such a controlled world is seen as desirable. If not, we have another reason for not realizing this specific technology. The two points can be illustrated with the example of nuclear energy. In this case, there are good reasons for questioning the feasibility of keeping the system of nuclear power production stable and reproducible (and hence safe) during a period of decades, centuries, and longer. Moreover, even if this control were feasible, there is the question of the desirability of the strict control and discipline needed to keep this technology stable and reproducible.

Andrew Feenberg's critical theory of technology constitutes another approach that combines theoretical, empirical and normative insights. Feenberg (1999) identifies two different "aspects" or "levels" of technology: the *functional constitution* of technical objects and subjects, called primary instrumentalization, and the actual *realization* of the constituted objects and subjects, called secondary instrumentalization. Thus, technology instrumentalizes humans and nature in two distinct ways. The distinction is analytic, meaning that in any actual technological artifact or system both aspects always go together. Feenberg develops this theory of technology by adding further characteristics of the two notions of instrumentalization. He specifies four "reifying" moments of primary instrumentalization (decontextualization, reductionism, autonomization and positioning) as well as four "integrating" moments of secondary instrumentalization (systematization, mediation, vocation and initiative). Primary instrumentalization is claimed to entail universal characteristics of technologies. Secondary instrumentalization creates further characteristics that might vary in principle but are in fact fixed by the dominant values and interests of a particular social group or society. The aim of Feenberg's critical approach, then, is to expose these underlying values and interests, and to argue for alternative – that is to say less oppressive and more democratic – secondary instrumentalizations of the technologies in question. An example of such a "democratic rationalization" is the bottom-up hacking of the French Minitel system in the early 1980s.

The aim of this essay has been to point to some of the central issues in past and present debates about positivism and anti-positivism in science and technology. While the older disputes focused on the doctrines and practices of scientism and technocracy, more recent approaches discuss the pros and cons of methodological naturalism and critical normativity.

Note

1. For reasons of space, the present discussion is restricted to constructivist studies of science and technology. Of course, "naturalism" is a much broader category, including for instance the influential evolutionary approaches to the study of science and technology (see, e.g., Lelas 2000).

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