Design and technoscience: historical intersections of science and technology

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Abstract

The term technoscience has gained greater currency in methodological discussions in history and philosophy of both science and technology since it came into circulation in the 1980’s, mainly through the influence of Bruno Latour’s works. It refers to a historically increasing entanglement of previously distinguishable goals, practices and methodologies that used to differentiate scientific research from technological praxis—an entanglement that supposedly characterizes the “postmodern” era.

A current reevaluation and reassessment of this situation is underway in the work of both historians and philosophers concerned with new relations and interactions between science and technology that are presently emerging. Much of this interest was precipitated in 2007 by a seminal, controversial and highly influential paper by Paul Forman, “The primacy of science in modernity, of technology in postmodernity, and ideology in the history of technology.” One of this article’s many remarkable characteristics is that, contrary to common practice, its title aims at fully displaying its principal thesis—if perforce very succinctly.

Taking my departure from some observations offered in Forman’s work I essay in this brief contribution an exploration of some cognitive aspects of the peculiar merging of scientific and technological practices encapsulated in the term “technoscience.” I focus on the parallel but diverse roles fulfilled by design activities in the creation of both conceptual and artifactual novelties. In so doing I continue and expand my reflections on the nature of tinkering in engineering inventions and their development, initiated with my contribution to the 2013 Junto Meeting, “Of thinkers and tinkerers.” I offer arguments for tracing the current entanglement of scientific and technological practices to a gradual synthesis of theoretical and practical interests—a cooperation that first coalesced in the designing practices of scientists and engineers. This was manifested most perspicuously in the tasks of designing scientific instruments and in the conceptual novelties they required and provoked.

Introduction

Three years ago at this forum I presented a paper titled Of thinkers and tinkerers (Fernández 2013) in which I briefly reviewed the changing fortunes of the cultural status of technology in relation to the superior traditional standing of science in Western
culture. This is the curious story of a centuries-long underestimation of technological work followed by a sharp and epochal reversal in recent decades. I attempted to relate this upheaval to the difficulty of untangling the science and technology strands from their increasing intertwinement in contemporary technoscience. This term encapsulates both the current enmeshment of scientific and technological practices and, simultaneously, the inversion of their relative ranking in what is often referred to as the postmodern era, i.e., our present time.

The term technoscience has gained increasing currency in methodological discussions in history and philosophy of both science and technology since it came into wide circulation in the 1980’s, mainly through the influence of Bruno Latour’s works. It refers to a historically increasing entanglement of previously distinguishable activities, goals, and practices that in former times sharply differentiated scientific research from technological praxis. For many authors this entanglement is a fundamental characteristic of the “postmodern” era.

In a seminal and controversial paper, “The primacy of science in modernity, of technology in postmodernity, and ideology in the history of technology,” and in other recent articles, Paul Forman has attempted to clarify the issues involved in this reversal and to discern the causes of this intricate technoscientific imbroglio (see e.g. Forman 2007, 2010). Various and wide-ranging reactions to these writings have also helped elucidate the nature of technoscientific issues (see e.g., Kline 2007, Mirowski 2007, Radder 2009, Alexander 2012). Among several remarkable characteristics of Forman’s 2007 paper is the fact that, contrary to much common practice, its title seeks to succinctly display its main central thesis.

As I concisely expressed it in my aforementioned paper, in technoscience

[At present] scientific and technological research and innovation are so closely intertwined, conceptually, economically and politically, that their respective natures and the intricacies of their interplay are hard to discern. Yet it remains possible to distinguish both their common characteristics and their contrasting differences (i.e., as to goals, cognitive styles, methods, etc.) when they are properly grasped as the outcomes of historically conditioned human endeavors (Fernández 2013).¹

In that opportunity I chose to concentrate on commonalities and differences across the distinct cognitive skills deployed by scientists and engineers in problem solving and novelty creation. I focused on the employment of tinkering in the creation of artifactual novelty and compared and contrasted it with the parallel operation of abduction in the

¹ Lacey gives a complementary characterization (Lacey 2012, p. 105): “This image of scientific research projects that the cutting edge of science is that which exploits the technological contribution to research, and which directly or indirectly furthers human powers to intervene into and control the world. This is what I call technoscience. In it, there is a distinction but not a concrete separation between science and technology, between, e.g., coming to know what is possible to observe, make, bring about and control at the nanoscale and the possible consequences of exercising such control at the level of everyday objects, and applying this knowledge to inform practical projects.”
pursuit of conceptual or theoretical novelty. Here I would like to continue this
examination by probing into the analogous though distinguishable roles of design in
science and in technology.

**Instruments in science and technology**

*Technology*, like the poor, has always been with us. Technological endeavor, understood
as a constellation of actions, practices and know-how directed at the creation and use of
artifacts, preceded the rise of Homo sapiens. In contrast to both practical knowledge
and Greek *epistéme, science* is the outcome of an extraordinary cultural novelty that
rose in the West some four hundred years ago. It was the result, among other things, of a
peculiar merging of mathematical reasoning directed to the understanding of nature
with the previously detached artisanal practices of designing, measuring and testing.

The fundamental role of scientific instruments in research represents an early but
mostly innocuous entanglement between science and technology. Theory, directed to
understanding and explaining natural phenomena, held central stage from the start. In
the view of most scientists instruments and instrumental expertise were merely ancillary
means for achieving the epistemic goals of scientific theorizing, i.e., understanding how
and why things are as they are. Occasionally, scientists’ reports of scientific discoveries
or advances included minute descriptions of the instrumental means employed in
effecting, observing or measuring the phenomena; nevertheless, such descriptions were
usually regarded as background material supporting the resulting scientific conclusions,
which were articulated and communicated by means of words, diagrams and
mathematical formulae.

Early scientific instruments, such as telescopes, balances and clocks, were at the onset of
the scientific enterprise evolutionary exaptations of artifacts originally developed to
satisfy more mundane necessities. Later on, as the instrumental needs of scientists kept
expanding, new devices were specifically designed to meet uniquely defined scientific
requirements. Such apparatuses were often known as “philosophical instruments” until
the mid-nineteenth century, while the scientists were known as “natural philosophers.”

For easy of presentation in what follows I will rely on examples from nineteenth century
developments, and on electric artifacts in particular.

At some point in the evolution of scientific devices a new, self-referential entanglement
of scientific and technological pursuits became manifest– a harbinger of their future
enmeshment in present technoscience. This was brought about by the need for new
instruments that embodied in their construction the very theories they were designed to
empirically support, illustrate or test. Take, for instance, nineteenth century voltmeters
and ammeters. Their design presupposes a basic theoretical knowledge of
electromagnetic phenomena: Ohm’s law is embodied in the arrangement of the
instrument’s parts. On the other hand, the measurements performed by means of those

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2 On the history of the terms “scientific instrument,” “philosophical instrument,” and
“mathematical instrument” in English, and their equivalents in modern European languages,
see e.g., Taub 2011 and Warner 1990.
artifacts could be seen as means for supporting or confirming the validity of the scientists’ understanding of the very laws that guided their design.\(^3\)

An area of intense interaction between scientists, engineers and entrepreneurs arose out of the protracted execution of a new type of large and complex enterprises, such as, for instance, the laying of submarine telegraph cables (see e.g., Hunt 1994).\(^4\). At times this situation prompted a reversal of the traditionally expected relation between science and technology. This situation was not by any means restricted to the British industrial expansion. Contemporarily, in the telegraph industry of the United States:

“...the machine shop, rather than the laboratory, was the locus of technological change for much of the nineteenth century. These shops were owned and staffed by mechanic-inventors who had begun their careers as telegraph operators and who often made inventions in response to specific requests by telegraph systems superintendents. These mechanic-inventors brought practical skills and intimate knowledge of the industry’s technology, rather than theoretical scientific training, to the process of invention. Indeed, their work was almost entirely devoid of theoretical development.” (D. Hounshell, cited in Krige 2006, p. 268).

New requirements and challenges encountered in the deployment of these emerging technologies necessitated instruments designed to detect and measure newly discovered or newly recognized aspects of the phenomena, which often came to light for the first time in the process of overcoming recalcitrant practical hurdles (See e.g., Wise and Smith 1986).

The design and construction of novel measuring devices required in turn the development and collective adoption of technical norms—specifically, the institutional standardization of the units of measurement. Concomitantly to these tasks intense scientific efforts were exerted to account for the new emerging phenomena in theoretical terms. These activities subsequently sparked scientific discourse about conceptually novel entities, defined operationally on the basis of their instrumentally measured attributes. Among them we find, in current parlance: temperature, work, potential gradients, electrical resistance and induction, capacitance, etc. The forerunners of the volt, the ohm, the ampere and the joule eventually acquired those official designations by the end of the century (see e.g., Jayson 2014, Hunt 1994).

Thus, newly defined units of measurement rose from a process in which scientific and technological interests overlapped and in time joined in close partnership. A new breed of practitioner came into existence: the scientist-inventor-engineer—a type best personified by William Thomson (Lord Kelvin).\(^5\) Such persons often carried out the diverse tasks inherent to this scientific-technological cooperation within their own

\(^3\) Lord Kelvin recognized a special form of this circularity in his efforts to establish the absolute temperature scale (see Chang and Yi 2005).

\(^4\) The dramatic career of William Thomson (Lord Kelvin) in his role as designer of both concepts and instruments is masterfully presented, within the larger social and economic context of British industrial expansion, in Smith and Wise 1989. See also Wise and Smith 1986.
individual work, pursuing their goals by immersing themselves in an oscillating give-and-take between practical and theoretical problems and solutions.

**Design in science and technology**

I think that it is precisely at this particular juncture—the invention and production of artifacts designed to attain the epistemic goals of scientific theorizing—that we would find the basic intersection where science and technology merged into a synergy from which they can no longer be extricated in practical terms. Notwithstanding this melding we can distinguish them conceptually, as attempted here—albeit with increasing difficulty as they continue evolving in close cooperation.

By focusing on the notion of design we arrive at a zone of convergence of scientific and technological work where both their commonalities and their differences are more sharply manifest. A very large and expanding literature currently exists on the subject of design as practiced in all spheres of human endeavor. There is a profusion of books, articles and even entire journals dedicated to research on design (e.g., *Design Issues*, *Design studies*, *International Journal of Technology and Design Education*).

This growing interest is of relatively recent date. Until the late 1960s the dominant conception among philosophers of science was that modern technology resulted from the straightforward application of the growing scientific understanding of nature. A classical expression of that view is Mario Bunge’s article “Technology as Applied Science” (Bunge 1965). In a publication that appeared 20 years later (Bunge 1985), he revisited the subject. Without abandoning his original position, he nevertheless points to a sort of autonomous creativity in technology in the pursuit of designing tasks:

> Technology may be conceived of as the scientific study of the artificial or, equivalently, as R&D (research and development). If preferred, technology may be regarded as the field of knowledge concerned with designing artifacts and planning their realization, operation, adjustment, maintenance and monitoring in the light of scientific knowledge (Bunge 1985, p. 231; my emphasis).

A few pages earlier he came close to identifying design and synthesis:

> [...] Design is often called synthesis, to suggest that it describes and prescribes the putting together of basic units or modules. [...] In any event, whereas analysis is characteristic of scientific research, synthesis is a goal of much of technology, where analysis is primarily a means. Thus, if an applied chemist has succeeded in analyzing a useful and scarce natural product, the industrial chemist may hope to synthesize it in the laboratory. The ultimate goal of analysis is discovery, that of synthesis is production (Op. cit., p. 226).

While I find rather odd Bunge’s contrast of science and technology in terms of analysis and synthesis, I think he was right in highlighting the importance of design in technology. His synthetic view of design seems to me of the essence, as I will later elaborate.
Design and the synthesis of theory and praxis

Historians and philosophers of technology have approached the subject of design from different perspectives. This brief contribution must concentrate on a single issue of particular relevance to its concerns. Starting with a paper titled “Design methodology and the nature of technical artefacts” (Kroes 2012) a lively and protracted discussion on the status of design in technology vis-a-vis its role in scientific practice was carried on among its author and various other researchers (see, e.g. Farrell and Hooker 2012, Galle and Kroes 2014, Farrell and Hooker 2015, Galle and Kroes 2015).

I cannot dwell here on the various points of partial agreement and contentious disagreement that punctuated these exchanges, but I would like to extract a fruitful lesson from the gist of their final, nuanced convergence (see Galle and Kroes 2015). This is the realization that the activity of designing artifacts, which is at the heart of technological practice and invention, shares fundamental cognitive components with scientific theorizing and experimentation. Both scientific and technological productions are inherently designing activities. I think that their commonalities as well as their differences stem from this shared cognitive core. Moreover, I will argue, such similarities and contrasts reveal themselves most conspicuously in the design of an important class of scientific instruments: measuring and detecting devices.

In contrast to non-utilitarian devices (e.g., musical instruments), typical human tools (e.g., hammers, shovels or pumps) are causally effective means for extending and amplifying biologically innate powers of human beings for forcefully transforming their surroundings. We use them to physically revamp our environment and attain practical goals. Measuring instruments, on the other hand, usually serve separate kind of interests. They represent a distinct subclass within a larger domain of intrinsically informational devices: information gatherers (e.g., microscopes), transmitters (e.g., telegraphs), recorders (e.g., books), processors (e.g., computers) and regulators (e.g., thermostats). Today’s ubiquitous smart phones are hybrids that incorporate all of these instrumentalities.

Measuring and detecting devices are an amalgam of causally effective and informational instrumentality; they open up new realms of reality and concurrently bestow upon us new organs for gaining access to them. Through their agency intangible phenomena, such as voltages or capacitances become visually revealed. This is also true for other instrument used for effecting or stabilizing the phenomena studied. As Boon cogently says:

The ontological distinction between the objects of epistēme and tēchnē becomes blurred once instruments are used in scientific investigations. Much of our empirical knowledge does not result from passive observation by means of instruments, but from interventions with instruments and technological devices. Observation as a source of empirical knowledge is extended by doing, by interacting and intervening with the world through our instruments (Boon 2009, p. 82).

All forms of designing are, as Bunge pointed out, synthesizing activities. But I think the
designing of typical scientific instruments (e.g., galvanometers or barometers) involves a higher order of synthesis, where theoretical and practical interests shed their traditional opposition to cooperate in the fulfillment of a novel kind of interest: the practical realization of impractical, (“disinterested”) interests in the pursuit of science’s epistemic goals —seeking explanatory understanding as an end-in-itself. As in other instances of authentic synthesis, the resulting compound displays emergent traits not detectable in the separate components. Scientific understanding incorporates but transcends knowledge that is merely practical or merely contemplative (in the sense of Greek epistéme). It is an evolving new species of knowledge. Similarly, scientifically based technology is a new species of practical transformation of the world.

**Philosophical coda**

If the above observations are correct they afford a novel perspective on the historical relationships of science and technology. Since the times of Galileo and Newton the deployment of scientifically designed instruments has empowered scientists and engineers with the means of transcending traditional conflicts between theory and praxis. Paradoxically, by means of scientific instruments the growth of highly theoretical “disinterested knowledge” underpins the accelerated rise of technological innovations —creations that open previously unthought-of levels of power and effectiveness. The pervasive network of growing instrumentality that so forcibly shapes our lives at present has evolved hand-in-hand with a parallel growth in the scientific understanding of nature.

In this vein we can envision the rise of modern science as the emergence of an unprecedented form of technology, directed to the construction of a novel kind of knowledge. This transformation constitutes a radical turning point in the evolution of technology. It can be usefully compared to similar major transitions in the evolution of living beings and their associations, such as the upshots of symbiogenesis or the jump from unicellular to multicellular organisms.

The changing societal evaluations of science and technology and their current entanglement are themselves the outcome of the accelerated growth of technoscience. They are probably temporary. Taking again our cue from the evolution of organisms and ecosystems we observe that rampant, unconstrained growth leads inexorably to the depletion of resources—an event frequently followed by the opening of new niches and the emergence of new, unpredictable forms of life.

**References**


Hunt, B. J. 1994. The ohm is where the art is: British telegraph engineers and the development of electrical standards. *Osiris*, 9, pp.48-63.


