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Two Approaches to Technoscience

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The first Western philosopher, Thales of Miletus, figures in two stories that illustrate very different images of science. Thales studied the patterns of the weather and one winter he predicted a bumper Olive crop. He optioned all the olive presses in Miletus and when the crop came in as predicted, he made a fortune renting them out at a profit. This version of Thales anticipates the alliance of science and business that prevails today. But there is another story in which Thales figures as an ivory tower thinker. It is said that one night as he surveyed the heavens, he slipped and fell into a ditch. An old woman passing by laughed and asked how he could understand the stars when he failed to see what was right there under his nose. This is the image of pure science that prevailed in philosophy and social thought until fairly recently.

That image was based on a certain understanding of theoretical physics the most basic of basic sciences. Theoretical physics is a mathematical discipline that appears on the surface very remote from the world of technology, both in terms of applications and experimentation. Physicists in their ivory tower were said to input data from experiments in their equations, leaving the applications to engineers and other lesser under laborers.

This image of physics as a pure intellectual discipline was supported by positivist philosophy of science which became dominant in philosophy departments in the English-speaking world after World War II. The term “technoscience” was introduced in the 1980s in reaction against positivism. The philosophers who introduced the term proposed a more realistic image of science, one compatible with Thales the scientific entrepreneur. They argued that science is essentially connected to technology. They pointed out that science has always had an applied aspect and that its vision of nature depends on what can be done with technological instruments and experiments. I sympathize with this view of science for reasons I'll explain in a minute. But the term technoscience needs serious qualification.

Some definitions of technoscience go beyond these initial claims and emphasize the breakdown of the divide between nature and culture that results from the manufacture of artificial materials such as computers and nanotechnologies. The emphasis of research may indeed have shifted but the refining of metal ores crossed this divide in the bronze age. Other definitions of technoscience claim that science is now fully incorporated into the corporate and public processes of advanced societies. This view is sometimes articulated in terms of post-modern relativism, as though the successful defense of a scientific theory could be compared to business success. The dangers of such a view are becoming clear with the election of science skeptics such as Trump and Modi in India.

In what follows I will propose a different definition of technoscience, one that I think is useful for understanding the political implications of the engagement of science and society today. I'm going to begin now by with a little personal history that helps to understand what is right about the basic concept of technoscience.

This is personal because I grew up in the midst of theoretical physics. My father was one of the young students sent by their universities to Germany in the 1930s to learn quantum mechanics at the source. By the early 1940s he was working in the physics Department of New York University. Around this time, Einstein wrote to Roosevelt proposing that the US attempt to develop an atom bomb. One day a colleague came to visit and asked where they could speak in absolute privacy. On the roof of the apartment building in which my father lived, he extended an invitation to join the Manhattan project. My father declined for reasons he never really explained and instead went to work on the development of radar.

His work on radar resulted in patents improving a special type of vacuum tube called a klystron. This is a very powerful generator of shortwave radio waves. Some years later, when I was about 10 years old, my father was invited for the summer to Stanford University where the klystron was invented. There he and his colleagues worked on the design of the Stanford Linear Accelerator, a high-energy machine which was used to accelerate electrons to relativistic velocities. The wife of one of his Stanford colleagues organized a little crystal radio club for the children of the physicists. While the dads were working with radio waves generated by klystrons, we kids were busy figuring out how to detect a radio signal with a chunk of silicon.

What is the point of the story? Theoretical physics may well have the abstract characteristics described by positivist philosophy of science, but it was no problem for a theoretical physicist to work on technology at his country’s call. One would not expect a literature or history professor to find this such an easy transition. And it was also possible for that work to lead to new instruments for detecting features of nature that had never before been seen, leading to further progress in pure science. Here the concept of technoscience is validated in its main outlines.

Because I lived this validation in my childhood I was never interested in positivist philosophy of science. I managed to avoid studying it and instead have always focused on technology. This has given me a somewhat different perspective on technoscience from many STS scholars, still implicitly engaged in the polemic against positivism. There is a tendency to overstate the case, to try to obliterate the distinction between science and technology. That worries me because it opens the door to political regulation of science on the same terms as technology. Routine regulation of technology protects us from many hazards, but one would not want scientific theories to be subject to politics. The Russians tried this with genetics and killed the science in their country for 50 years. Today Trump is engaging in the same kind of manipulation of climate science. From this point of view one sees the advantage of the positivist view of science. By isolating science completely from the world of technology one protects it from intrusive regulation.

There is a history behind this aspect of the question of technoscience. The sharp division between theory and application was instituted by the nineteenth century research university. Pure science was granted the dignity of a disinterested search for truth and located alongside fields such as literature and history from which no practical or pecuniary application was expected. This supported the independence of science and the right of scientists to pursue problems of basic importance. Scientists saw themselves as intellectuals involved in higher culture on terms similar to literary scholars or musicians. Of course there have always been important applications of science, even as it was institutionalized in the ivory tower in the late nineteenth century. That was when vaccines and artificial dyes were invented by great scientists. But maintaining the idea of pure science was still important for legitimating work that had no obvious practical value.

The emphasis changed after the Second World War. Three scientific innovations played an important role in the allied victory. These were the atom bomb, radar, and cryptography. After the war the American military saw science as a key to victory in the Cold War struggle with the Soviet Union. The military proposed to fund science while bringing it under direct military control. This would have involved rigorous security, secrecy, and draconian punishments for violations of the new regulations. Scientists resisted and succeeded finally in creating the current system of grants and contracts administered by universities. In this way they protected their independence while benefiting from the vastly increased funding available for scientific research. The ideology of pure science played an important role in the success of this compromise with the military. Let the scientists pursue what I. I. Rabi called the “endless frontier” of research in the university, and eventually useful applications will trickle down.

This background helps to explain the social function of the ideological notion of pure science. The fact that the personal experiences and activities of scientists contradicted the ideology was easily overlooked. The purity of so-called pure science was no obstacle to scientists relying on ever more complex technologies in their exploration of nature while contributing ever more applications to the military and the economy. But the gap between the idea of pure science and the technoscientific reality has been eroded in recent years. The biological sciences are now the new paradigm science, replacing theoretical physics. The distinction between pure and applied science breaks down in biology to an unprecedented degree. A great deal of biological research is directly supported by pharmaceutical companies and other businesses seeking profits rather than truth. And while much progress has been made, the consequences are exactly what the scientists feared from military control, namely secrecy and corruption of research by external forces.

Of course there are still obvious differences between scientific research and most work with technology. Those differences cannot be erased by a clever terminological invention such as “technoscience.” Clearly, the problems faced by truck drivers and construction workers are rather different from the concerns of theoretical physicists and even pharmaceutical researchers, although they all use technology. It makes no sense to confound them all in a universal "technoscience." The concept of technoscience has a role in demystifying claims of purity that are now far more unjustified than in the period before World War II, but it must be deployed with discretion. We still need a distinction between science, whether we call it "technoscience" or not, and ordinary technology.

In an earlier paper I suggested a definition of "technoscience" based on these considerations. I proposed that we reserve the term for scientific research that has an immediate role in the development of applications. In such cases theory and application are not separate phases that can be pursued in isolation from each other but are pursued simultaneously. This is the case, for example, where the experimental apparatus is a prototype of a future technology. Pharmaceutical research meets this criterion, but in the conclusion of this paper I will propose a broader application of this concept of technoscience.

So far I have been describing the social world of science. The concept of technoscience introduces a more realistic picture of that world than the earlier vision of pure science. But it also raises a fundamental question. What is it about scientific thinking that lends itself so readily to technological application? What is it about science that ties it to a world seen through technology? Something more basic than social theory is necessary to answer these questions. I want to now consider how several philosophers have attempted to explain the connection between science and technology.

I will begin with Martin Heidegger's reflections on science and technology. I will then discuss Marcuse's related reflections. Note that Marcuse was Heidegger's student and offered an alternative to Heidegger's views in his famous book *One-Dimensional Man*.

Heidegger and Marcuse a share a key concept. This is the transcendental notion of object construction. Each field of research defines a specific kind of object through its methods and concepts. In one sense this is obvious. Physics for example considers matter in motion while biology considers life, and so on. But these philosophers regard such definitions as only the beginning of a far more detailed specification of the way in which a certain cross-section of reality is carved out for investigation. That refined cross-section constitutes or constructs the object of study, which is not to be confused with raw experience of the world.

This approach emphasizes the role of the subject of knowledge in a way that excludes common sense realism. Neither Heidegger nor Marcuse deny that science studies reality, but given the role of the subject in object construction there is no reason to grant science an exclusive license on the truth of the real. Other object constructions may reveal other aspects of the world, hidden to science by the limitations of its construction of its object.

Heidegger argues that modern science is radically different from ancient science. They cannot be compared so the concept of progress is irrelevant here. The difference stems from different conceptions of nature. The modern scientific projection of a quantifiable idea of nature is quite different from the idea of nature in earlier times. Ancient science considers nature as self moving, self creating. Its model of nature is clearly derived from biological growth. Modern science conceives nature in terms of what Heidegger calls a “ground plan” that anticipates in advance the sorts of things that can appear as objects of research. Heidegger's example is physics for which nature is stipulated to consist of a self-contained system of motion of units of mass related in time and space. Motion here means only change of place in a uniform continuum. This definition of the object suits it to the establishment of exact mathematical magnitudes. Modern science relies on mathematical procedures since it defines its object in advance as the sort of thing that can be measured and counted.

Heidegger notes that modern science produces an image or representation of the world. He calls this a “world picture,” that is, a supposedly exhaustive representation of reality. Reality is simply what can be represented by science. This seems obvious to us: science gives us an image of the cosmos we accept as a more or less accurate picture of reality. But according to Heidegger this is a uniquely modern way of understanding the real.

Ancient Greece, for example, did not identify the essence of reality with a representation, a picture, but with a process, the phenomenon of growth. The Greeks encountered a self-creating, self-moving nature characterized by intrinsic potentialities. Their reality “moves” from one level of actualization of potential to another higher level as it develops. The same word, *kinesis*, signifies this qualitative change and mere movement in space. The developmental process cannot be measured in quantitative terms and gives rise to no theoretical picture. Instead it posits a meaningful nature with its own life independent of the subject. The modern scientific picture of nature eliminates the notions of self-movement and intrinsic potentiality. Nature is meaningless and utterly dependent on the subject for which it serves as a raw material available for instrumental control and domination. The interconnection of science and technology lies in that original ground plan which exposes nature to both representation by science and control by technology.

Heidegger intended this theory to be critical in some sense but not anti-scientific. Rather it was the whole modern way of being in the world that he called into question. What troubled him most was the absorption of the human being into the ground plan of science as just another object subject to representation and control. But he did not blame science for this but rather the spirit of the modern age. This critique of modernity leaves very little room for alternatives. Heidegger rejected the sort of thing that we think of as New Age re-enchantment. Using myth or religion in order to reestablish meaning in life would simply instrumentalize these spiritual resources and so recapitulate the original problem of universal technification. He offered no way out and in his last interview said "only a God can save us."

I want to turn now to Marcuse's alternative approach which has much in common with Heidegger's but offers a more hopeful alternative. You're probably aware that Marcuse taught at this university. I did my doctoral work with him here and that ultimately set me on the path of research on technology I'm still following. But as you will see I have some differences with his approach.

Marcuse's discussion of science follows more or less along the lines laid out by Heidegger. He too regards the basis of science as a certain concept of nature which exposes it to quantification and control. He quotes Heidegger as saying, "modern man takes the entirety of being as raw material for production and subjects the entirety of the object world to the sweep and order of production." The essence of modern science is the elimination of intrinsic potentiality in favor of measurable facts. What the Greeks thought of as objective potentialities are now dismissed as mere cultural prejudices. They are no longer considered any more significant than the arbitrary goals of human subjects. Our model of technical action is not cultivation but clear cutting. This surrenders science and technology to the prevailing social power. Reality itself no longer offers any guidance for action and only the goals of those with power stand a chance of being implemented.

Marcuse's analysis differs from Heidegger's in arguing that this instrumentalist conception of nature is not due to modernity as such but specifically to capitalism. He argues along the lines anticipated by Husserl that science is based on practices of quantification and control in everyday life that it refines and develops. Those practices are shaped by capitalism in modern times. This would explain why modern science and technology have arisen at the same time as capitalism and have turned out to serve it well.

Attributing the rise of science to a specific socioeconomic system suggests the possibility of change through historical action. Marcuse was a Marxist who believed that a revolution would modify not only economic arrangements but the very conception of nature. A socialist modernity would integrate science and art in a new conception of nature and a new, more benign technology respectful of nature's potentialities. Marcuse thus looked forward to the recovery of the idea of potentiality, banned from the modern scientific idea of nature. Although difficult to defend philosophically, this notion appeals intuitively to our sense that things have gone terribly wrong in recent times. For example we do believe that human beings have potentialities that can be frustrated or realized depending on their social and economic circumstances. Nature appears to us increasingly threatened by our crude technological assault on its integrity. In some sense this suggests that nature has potentialities we can favor or deny.

Nevertheless it is difficult to see how modern science could function in the context of a different concept of nature. Marcuse seems to have been aware of the difficulty because he rejected the notion of a qualitative physics as an alternative to the science we practice today. That would be a science like Aristotle's that identifies the essence of things rather than measuring them. But essences are by definition qualitative. Quality is precisely what is at stake in the notion of potentiality. So how does Marcuse intend to avoid regression to a qualitative science? Furthermore, in the absence of a scientific ground for the identification of potentiality what grants our notion of it objective status? Aristotle did not have this problem because he took his culture's conventional ideas of potential for granted. Heidegger too did not need to confront this problem because he left the future in the hands of God. But Marcuse projects a human future, humanly created in harmony with the potentialities of nature and human nature and so faces great difficulties.

Marcuse developed these ideas in the early 1960s. At that time the environmental movement was small, as were other social movements that challenged science and technology. Social science was so strongly imbued with positivism that it offered no useful starting point for the sort of cognitive reform Marcuse envisaged. As a result his suggestions are very abstract. He argues that art is the repository of ideas of potentiality that are neither conventional nor subjective. If art could infuse science with purpose and meaning, a different idea of nature would emerge. This does not seem very convincing today, but I think our skepticism is in part due to the fact that we have other ways of resolving the problem Marcuse set himself.

We have concrete ways of envisaging the reform of technoscience based on actual social movements in domains such as environmentalism. Unfortunately Marcuse did not return to his theory of science to revise his earlier views in response to these movements. This is our task. From our perspective today we can make sense of his position in a somewhat different way than he intended while remaining faithful to his argument for potentiality as an aspect of nature.

The empirical study of science today has made the point that the boundary between science and technology is far fuzzier than was assumed at the time Heidegger and Marcuse developed their theories. In a sense this confirms the intuition of these philosophers. They posited a transcendental link between science and technology, independent of the empirical trends traced by historians and sociologists. For them the point was not that science was applied or relied on instruments to perceive the world, but rather that science conceived nature as the sort of thing that could be measured and controlled.

While this led Heidegger to despair, Marcuse proposed an alternative concept of nature's potentialities. He argued that the scientific object construction would again include potentialities in a socialist society. These potentialities would not be mere conventions but would respond to the creative imagination. But it turns out that we have not had to await a socialist revolution to see fundamental changes in the concept of nature. Already the reaction against the destructive aspects of capitalist technology has motivated significant changes neither Heidegger nor Marcuse anticipated.

Sciences now proliferate that operate across the boundary between science and technology maintained by scientific institutions in the past. Technoscience, the intrinsic relation of science and technology, is not just a function of the concept of nature, as Heidegger and Marcuse argued, but a present disciplinary reality. Technosciences that barely existed for these philosophers are now central to our vision of science. These disciplines respond to properly epistemic questions posed by researchers while simultaneously addressed other question posed by corporations, governments and the general public. And as Isabelle Stengers argues, these are all legitimate questions responding to different concerns and different understandings of nature. Together they lay out the terrain on which science, technology and society now interact. These interactions are not just external but engage a mutual co-construction.

In some of these technosciences potentialities play a role. For example, consider ecology. This science employs the methods of scientific research. It conceives nature along the standard lines of physics, chemistry, and biology. Quantification lies at its core. But at the same time it is animated by what traditional philosophy would call a conception of the good. It is dedicated to explaining nature in terms of ideals of health and sustainability that refer to potentialities of its objects. These ideals respond to concerns of citizens but they infuse the science by orienting it toward specific types of problems and measures.

Climate science, for example, does not have an idle interest in the composition of the atmosphere but is entirely oriented around predicting effects that will impact human civilization. The object “climate” did not exist in its present form until it was constructed by this science. Climate science is not simply applied to policy, but arises from it. The potentialities of the natural systems that favor human civilization are not arbitrary goals but must be articulated through the concepts developed by the sciences that posit them. Sustainability refers to conditions under which the environment can support human life. From the standpoint of “pure” science, the earth can get along fine without us, but disciplines such as climate science are predicated on the problem of human survival and serve that end by defining thresholds of change.

Technoscience in this sense answers Marcuse's requirement that science recover a notion of potentiality. We could extend this argument to other disciplines as well. Urban planning, architecture, epidemiology, medicine, even management theory can all be developed around a concept of the good of the populations they affect. And this good is not simply a subjective wish but flows directly from the demands of the individuals concerned and the study of human needs and capacities in the contexts in which these disciplines intervene.

Here the constitution of the natural object for research and the application of theoretical knowledge through technology form a single whole that cannot be disaggregated into mechanically separated parts. Of course there is a division of labor between different aspects of the network formed by researchers, their instruments, policy makers and technical experts. But each aspect of the network is defined by its relation to the whole. And that whole posits a nature which has the intrinsic potentiality to favor human life.

In conclusion I think we can find a use for the concept of technoscience. It is not just a question of business financing of research in pursuit of short term applications. Nor is it interesting, after the death of positivism, to point out that science depends on technological instrumentation and experiment and creates artificial objects with these means. The concept of technoscience must also be carefully distinguished from the larger domain of technology in which science plays only a minor or routine role. The autonomy of science from direct political control must remain an essential feature of our concepts of science and technoscience. But with these limitations the concept can help us understand the emergence of new disciplines that incorporate science as we know it in a larger framework that recognizes the imbrication of nature and humanity.