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The rise of modern technoscience: some conceptual considerations from the perspective of S&T studies

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Abstract. The article examines the heterogeneity in modern conceptions of technoscience and the need for their rethinking in the perspective of S&T studies. The specific "mainstream" in the study of technoscience is identified, on the basis of the so-called convergent approach. The article proposes the generalizing thesis that modern science is naturally evolving towards technoscience, and grounds the respective S&T studies conceptual framework providing a view of the essence of technoscience as related to the creation of a symbiotic and synergetic relationship between science and technologies, as well as a view of the scope of this phenomenon, which, according to the author, encompasses all branches of modern science, to various degrees. A brief reconstruction is given of the development of technoscience in the perspective of the proposed conceptual framework. In conclusion, technoscience is described as the new paradigm of the future, which will actively affect social development and has the potential to significantly change our way of life.

Keywords: technoscience, conceptual clarification, S&T studies, convergence of science and technology, social responsibility of R&D

1. Introduction

In the last few decades, science and technologies have grown in both size and scale, and are broadening their range of significant social impacts and consequences. At the same time, they are becoming increasingly inter-determined: while technologies are largely science-based, they in turn are becoming an important precondition for the development of science, and their connection to society is also becoming stronger.

This situation has led to the concept of ***technoscience***, introduced for the first time by the French philosopher Gaston Bachelard in 1953 and disseminated later by the Belgian philosopher Gilbert Hottois. However, at a conceptual level, the idea of unity between science and technologies is much older. According to Ian Hacking, we may consider the great Renaissance thinker Francis Bacon to have been its originator; he was the first to link science to technology, and to associate it with the concept of "power". Bacon claimed that science gives knowledge about the causes of phenomena and at the same time generates a capacity for effective intervention in those phenomena, i.e., he presents science as a combination of representation and intervention. "*Bacon taught that not only must we observe nature in the raw, but that we must also 'twist the lion's tail', that is, manipulate our world in order to learn its secrets*" (Hacking 1983, 149).

Evidently, the concept of "technoscience" is not an empty theoretical construct but reflects an important modern phenomenon, underlying which are some very important objective developments and processes in science and technologies. However, there is a great variety of views in scientific circles as to how this concept should be interpreted, along with a certain accretion of trends and a gradual conceptual clarification - these developments may be explained from the perspective of S&T studies and the system approach. The present article is devoted to precisely this research problem: is it possible, based on the numerous and varied ways of conceiving of technoscience, to outline some characteristic "mainstream" in the concept's definition and thus to outline a new conceptual framework for the modern technoscience?

2. Basic currents in the development of the concept of "technoscience"

The initial concept of technoscience became the basis for a conceptual proliferation, linked contextually to different dichotomies: science - research; fundamental - applied science; natural sciences - engineering sciences; science - technologies; "propositional knowledge" (I know that...) - "procedural knowledge" (I know how...); study of the natural - study of the artificial; science - social environment.

For instance, the constructivist understanding of technoscience, whose main proponent is the sociologist of science Bruno Latour, makes a distinction between the concepts of "science" and "research": "*In the last century and a half, scientific development has been breath-taking, but the understanding of this progress has dramatically changed. It is characterized by the transition from the culture of 'science' to the culture of 'research'. Science is certainty; research is uncertainty. Science is supposed to be cold, straight, and detached; research is warm, involving, and risky. ... Science produces objectivity by escaping as much as possible from the shackles of ideology, passions, and emotions; research feeds on all of those to render objects of inquiry familiar*" (Latour 1998, 208). Latour thus criticizes the concept of "pure science" as fictional, and accepts the term "technoscience" as generalizing the characteristics of the research process in its heterogeneity and commitment to individuals, nature, society, economics and politics.

According to the post-phenomenological interpretation of Don Ihde, the American philosopher of science and technologies, technoscience is science embodied in instruments. He takes a purely instrumentalist approach to science, equating it with technoscience in the sense that it cannot fulfill its functions without using research instrumentation (Ihde 1991). Jan Schmidt holds a similar view: "*Technosciences - and modern sciences - depend heavily on instrumentation and experimentation, on intervention and construction. Without intervening, shaping and manipulating, a scientific methodology does not exist*" (Schmidt 2011, 103).

According to another conception, technoscience - in contrast with classical science of the early 20th century, whose applications are mostly the result of a scientific understanding of certain aspects and objects taken from nature (such as microbes, molecules, organisms, etc.) - is based on "*the Sciences of the Artificial*" (Simon 1996). In support of this view, the philosopher of science Alfred Nordmann holds that technoscience involves an "entanglement" of the natural and artificial. According to him, engineering knowledge and the engineering sciences can also be considered technoscience inasmuch as they involve the creation of artifacts. Some other scholars also uphold this view.

Technoscience is often viewed along the axis of fundamental vs. applied research. According to a perspective that we may call traditionalist, technoscience is associated with the application context of research. Other authors refer to "hybridization" between fundamental and applied research, the two of which merge in the concept of "technoscience". The latter is conceived of by some authors as a kind of synthesis between the concept of "propositional knowledge", or "I know that...", and "procedural knowledge", which corresponds to the question "how?", developing at a later stage into "know-how".

In English-language literature, the term "technoscience" became widely used after the year 2000, becoming an object of research interest as a concept indicating simultaneously the technological and the social contexts of science. Technoscience is seen as a term reflecting the generally accepted view both that scientific knowledge is socially determined and that a suitable material environment is required for its stability and functioning over time. "*Technoscientific knowledge is assumed to be, in the long run, an adequate instrument to obtain a competitive advantage in the global market, to ensure growth and wealth, and to solve societal problems. Insofar as interests are the starting point of technoscience, the culturally well-established dichotomy between facts and values is blurred at the very beginning of technoscientific practice*" (Schmidt 2011, 103). The so-called feminist model of technoscience, increasingly popular at the start of the new millennium, introduces key terms such as social responsibility of science and technologies, control, "technologies of humility", etc.

Gaining ground is the view that in a "knowledge society" and under the so-called Mode 2 of knowledge production, the difference between science and technologies is becoming inessential, the applied context of research is becoming predominant, a pressure appears for higher social relevance of science, and the public plays an increasingly important role (Gibbons et al. 1994). Many modern philosophers of science (Larry Laudan, Karl Popper, Ian Hacking) also emphasize the role of a number of social, ethical, political, and economic factors of the production of scientific knowledge, referring in this way to the concept of technoscience. "*If technoscience is a value-laden enterprise (epistemological and social values), then a philosophy of technoscience may be enlarged to pay attention to science and technology policy*" (Queraltó 2008, 122). Including these new aspects, Queraltó introduces the concept of "pragmatic philosophy of technoscience".

Overall, despite the large divergence in conceptions of technoscience, what we have defined as the ***convergent approach to technoscience*** has increasingly and firmly asserted itself over the years. This approach refers to the blurring of differences between science and technologies and can be traced back in time to the 1980s, when the British sociologist Barry Barnes wrote, "*I start with the major reorientation of our thinking about the science - technology relationship which has occurred in recent years … We recognize science and technology to be on a par with each other. Both sets of practitioners … are in fact enmeshed in a symbiotic relationship*" (Barnes 1982, 166). And twenty-three years later, "'*Technoscience*' *is now most commonly used in academic work to refer to sets of activities wherein science and technology have become inextricably intermingled, or else have hybridized in some sense …* '*Technoscience*' *has come to be regarded as something especially characteristic of the present*" (Barnes 2005, 142).

The much greater "embeddedness" of scientific knowledge in the creation and application of new technologies is the most notable trait of technoscience. Thus, the German sociologist Wolf Schäfer defines technoscience as "*a hybrid of scientizied technology and technologized science*" (Schäfer 2002). Another author states, "*This current interdependence between science and technology is expressed precisely by the term technoscience. Nowadays it is a fact that this connection makes it very difficult to establish precise boundaries between both … the border line between science and technology becomes imprecise, because it is not possible to establish where each one begins or ends*" (Queraltó 2008, 113, 116). Similar theses have been expressed by many other researchers (Nordmann 2006; Schmidt 2011). Thus, the firm view is gaining ground that science and technologies have become mutually inseparable, creating the new reality of technoscience. "*But if we look at technology, we can at most admit a conceptual or an analytic distinction, without any real separation from science, since they are concretely intertwined and, so to speak, consubstantial [. . .]. This in particular justifies the use of the term technoscience for designating this new reality*" (Agazzi 2001, 127).

In other words, the technogenic environment is becoming the natural field of application of science, the normal environment for the development of science. As it converges with technologies, science is gradually passing the boundaries of its natural domain of functioning and is turning into the new phenomenon of technoscience.

Alfred Nordmann qualifies the passage from science to technoscience as an"*epochal break*" (Nordmann 2011). According to him, the scientific enterprise is marked by a strict distinction between representing and intervening, nature and culture, science and technology; but within technoscience, these distinctions are no longer possible and are not required. Other authors go even further, arguing there is an "*increasing hybridization of science, technology, industry and society*" (Weber 2011, 160). It should be pointed out, however, that Alfred Nordmann does not believe science as a whole is transformed into technoscience, but argues "*there is a multiplicity of sciences*" (Nordmann 2011, 21), wherein some sciences acquire an increasingly applied orientation, passing into technoscience, while others remain "pure sciences" that simply search for the truth (a thesis we will try to refute below).

3. A generalized thesis regarding technoscience from a S&T studies perspective

Considering the conceptual developments described above from the viewpoint of S&T (Science and Technology) studies[1], we may assert that ***modern science is naturally evolving towards technoscience***. In order to ground this view, we will proceed from the model of science as a system, and taking this as a reference point, we will explicate the new features that characterize technoscience.

Previous works have offered a new schema for the system of science as composed of three basic elements: the ***cognitive*** (representing a body of dynamically developing scientific knowledge); the ***social*** (science's social body as a carrier of the activity aspect of the system of science, including: the individuals who create scientific knowledge; the research institutions and scientific communities; and the mutual relations between these in the context of the production of scientific knowledge); the ***infrastructure of science*** (the material and information resources ensuring the conducting of research). This schema explains the importance of the environment in which the whole system functions and with which it constantly interacts. It stresses that the development of the system of science and its interaction with its surroundings bring about changes in the system's components and way of functioning in view of certain goals (Ivancheva 2015). However, in the context of modern developments in science - specifically, the passage to the phase of technoscience - we should also place within the social component (besides the scientific social body) the ***social recipient*** of new knowledge. This is because the interrelations between science and society are changing in important ways, and the role of public demand from science, external participation and control in science, are constantly gaining in importance. Moreover, a new system component should be added, namely, ***technologies and artifacts***, which are becoming an inseparable attribute of scientific research that not only gives functionality to the scientific infrastructure but is in itself a significant object of research (and at times an agent of research in the form of high level artificial intelligence) and a kind of research product that is different from "pure knowledge".

On the basis of this system model, we propose a **new S&T studies conceptual framework** that provides an understanding of the nature and scope of technoscience. We see technoscience as an alternative to the traditional division between science and its technological applications; and as a process of "symbiotic relationship" of the two that goes on in active interaction with the public. In our opinion, this large-scale transformation, a very important one in our times, affects the whole of modern science, not only its separate disciplines, and is channeled in several main directions.

First, scientic research and the production of the respective technological applications become ***interrelated in their purpose orientation***. They both aim at results that, in addition to enriching the knowledge, would be useful and have a high potential for expanding human capacities. For instance, in parallel

[1] An interdisciplinary research field focused on science and technologies, their relations with society and their impacts on human development.

with the development of quantum mechanics as a theoretical discipline, technologies are being developed for the creation of a "quantum computer" and successful experimentation is being conducted for the teleportation of micro-objects.

The view on "scientific research" and "development activity", or "technological innovation", as separate, independent processes is changing: they are merging into a new kind of ***hybrid activity*** containing both purely research-related elements and methods and, from the very start, many applied-technological aspects. "*A proper explanation of scientific change requires an analysis of the technological infrastructure of science and the way it interacts with scientific theory. Here … lies a new and promising research program*" (Feenberg, Hannay (eds.) 1995, 13). In many respects, "pure research" and its applied context can no longer be differentiated. This is the case of biomedical research aimed at devising new medicaments for fighting cancer, of material and computer science, etc. "*Nanotechnologists for instance, often claim that they are not interested in application per se, and do rather see themselves as pursuing genuine knowledge by learning to manipulate atoms or molecular processes. Or else, synthetic biologists often make a special claim for an epistemology of 'constructing' or making as the source of real knowledge*" (O'Malley 2009, 381).

Of essential importance is the fact that the influence of science and technology, two until recently separate spheres, is now mutual and two-way. On the one hand, scientific achievements are certainly a precondition for the development of new technologies, and no modern innovative technological product could be achieved without investing intense research work. On the other hand, modern technologies themselves create incomparably greater possibilities for the development of science (here, we need only recall the role of information and communication technologies or the importance of modern research infrastructures and experimental equipment, such as accelerators, bio laboratories, satellites, medical research apparatuses, etc.). Importantly in this connection, Joseph Pitt finds that "*in mature sciences, it appears that the more embedded the science is in its technological infrastructure, the more the infrastructure drives the science*" (Pitt 2011, 101).

These trends were identified long ago by the German philosopher Martin Heidegger: "*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*" (Heidegger 1977, 14). Edward Layton reached similar conclusions: "*Science and technology have become intermixed. Modern technology involves scientists who 'do' technology and technologists who function as scientists … The old view that basic sciences generate all the knowledge which technologists then apply will simply not help in understanding contemporary technology*" (Layton 1977, 210).

Simulation modeling is a typical example of the decisive intervention of technologies in the process of research. The most apt assertion in this regard seems to be Nordmann's: "*We encounter the hybrid 'technoscience' where theoretical representation becomes entangled with technical intervention*" (Nordmann 2006, 2). That is why the terms R&D and "innovation development" are the best process referents for the general S&T studies concept of technoscience. "*In the modern* *age technology was viewed as applied science, while in postmodernity science is regarded as a kind of applied technology - its intellectual and physical control of phenomena depends on technology and a technological mode of thought*" (Nordmann, Radder, Schiemann 2011, 6).

Technologies have been found to exert an influence not only on the natural sciences but on social sciences as well. The Bulgarian economics researcher Rositsa Chobanova, for instance, has emphasized their role in the creation of new theories and concepts of social development (Chobanova 1998). A "hardening" of so-called "soft sciences" is taking place, based on the increasing introduction of mathematical methods of study and the use of new technological solutions (for instance, computer reconstruction and visualization in architecture and archeology, modern physicochemical methods for analysis and dating of historical artifacts, genetic studies in anthropology, application of information technologies in linguistics, etc.). All this leads to the easy inclusion of the social and human sciences in "technoscience".

Similarly oriented is the use of the concept of "social innovation", which has a strong instrumental, hence technological, connotation, and designates the application of new methods and approaches (including scientific and technological logistics) to the solution of social problems (in the fields of education, healthcare, environmental protection, communal services, etc.). Under the category of social technologies, we may likewise assign management technologies and modern social management, and the solution to many (including innovative) problems connected with regulation of social processes.

Further on, the ***very objects*** of technoscientific research are being transformed: unlike the research objects of "pure science" (of course, we are not referring here to those of engineering science disciplines), the objects of technoscience are no longer natural creations, phenomena or processes, but are predominantly artifacts, i.e., objects with artificially added components or characteristics (for instance, nano-pipes, therapeutic viruses, electromagnetic pollution, etc.). "*The use of technological means transforms the research object in such a way that it becomes a technological object and not just a scientific object as such*" (Queraltó 2008, 116).

Even humans themselves will gradually become artifacts of this kind. Thanks to genetic engineering, the achievements in biomedicine, nanotechnologies, information technologies, new technologies like 3D printing, and in cognitive science, humans will gradually incorporate a number of artificial elements in their bodies, such as artificial organs and tissues (or even artificial blood), and electronic-computer equipment (for instance, "an artificial hand" or an exoskeleton) meant to expand the capacity of the human motor system, senses or intellect. The natural environment and the earth's proximate outer space are also subjected to powerful anthropogenic influences corresponding to the concept of technoscience. Moreover, radically new social phenomena are appearing, such as the so-called associated public intelligence, built in the form of network communities that are technologically based on communication networks and include artificial intelligence systems.

On the other hand, it has already become almost impossible to distinguish between a ***purely scientific and an applied-technological achievement***. Even strictly fundamental scientific discoveries are made with the help of new vanguard technologies (a typical example is the discovery of X bosons by means of CERN's Large Hadron Collider, which represents an enormous high tech research infrastructure). "*So this technological infrastructure is a very decisive factor for scientific discoveries*" (Queraltó 2008, 116). And in turn, no modern innovative technological product can be obtained without intensive research labour.

In regard to the growing requirement for social responsibility of modern science, and the increasing ***commitment of science to public needs and attitudes,*** as well as the political formulations regarding the greater applicability of research results, the concept of "technoscience" reflects these objective trends much more adequately, including in itself concepts like "directed basic research", "implementation science" (referring to the application of scientific results to clinical practice), etc.

By assumption, technoscience implies wide public participation, chiefly in the form of public discussion on policy decisions related to socially sensitive areas such as bio and nano technologies, genetic engineering, safety of mobile communications and their infrastructure, etc. As a concept, technoscience corresponds to the requirement for greater objectivity and ensuring the public interest in the assessment of, and control over, scientific results and products by means of "external reviewing" and public participation in discussions on ethical issues. The stance has gained ground that a shared culture of responsibility should be established with regard to the unforeseen challenges and possibilities that might arise in the future. These views fall under the concept of "ethicization of technoscience", where the problems of management and development of modern applied sciences and technologies are approached strictly in the framework of ethical discourse.

In general, technoscience exerts a powerful and irreversible impact on the climate, energy sources, security, the modes of work, education, and recreation, and even on human reproduction; it has the potential to bring about changes not only in the habitation environment but also in the relations between people and their environment, gradually transforming the latter into an extension of the individual, into a virtual reality deeply enmeshed in the objective world, active, "intelligent" and adaptive, governed by human reason and responsive to human interests and needs. In other words, technoscience has major social consequences, which make it essentially different from the classical science and technologies of the past. The development of technoscience is also connected with the appearance of new innovational infrastructures such as "smart cities" and "living labs", where scientific-technological innovations are turned into social-economic innovations with long-term perceptible consequences for the lives of citizens in terms of security, estheticization, engagement, social relations, and economic development.

In the organizational aspect, our general S&T studies thesis regarding technoscience is in accord with Ramón Queraltó's conception of "technoscientific company": "*A technoscientific company is a complex group of specialized agents who coordinate themselves in order to reach common objectives of technological production. This group consists of scientists, technologists, managers, economists, programmers, permanent evaluators of the process, etc. The most important point to underline here is that* *the production of science and technology is no longer the work of a homogeneous company - the group of scientists or technologists only, for example - but it is a collective and heterogeneous practice, namely, a global action in which, in addition to pure researchers, there are other agents that organize the processes of innovation and production*" (Queraltó 2005, 188).

Let us make a **brief overview** of the development of technoscience from the perspective of the new conceptual framework proposed here.

Until recently, science and technologies were looked upon as completely different from each other: whereas the mission of science was to study natural and social regularities, the function of technologies was, in this perspective, to be an instrument for modifying nature. In the past, the creation of technologies and artifacts was in many cases not based on scientific theories. For its part, science was curiosity-driven and aimed to know, rather than transform, the objective world.

With the growing complexity of technologies and their increasingly important role for society, there came a point when their intensive development became impossible without a solid scientific foundation. In parallel with this, science became increasingly dependent on the development of technologies: "*contemporary science is technological (in the sense of being dependent on the use of hardware artifacts) in a way that classical science never was*" (Hickman 1995, 212). Technologies gave impetus to scientific research also through the numerous unanswered questions raised by technical developments. There began a process of ***converging of scientific knowledge and its technological applications***.

The anthropogenic factor is becoming ever more decisive, and is intervening ever more strongly and definitely in the natural systems. So much so, that the artificial and the natural are reaching a high degree of integration; there is hardly any element of the natural environment that is not being modified into an artifact through human intervention. This is a result of the incredibly enlarged possibilities for manipulating the environment and humans themselves - a result due to scientific-technological development. At the same time, a qualitatively new stage of development has been reached not only in science and technologies but also in the mutual relation between them and society. Society is intervening ever more firmly in the activity of scientific research and innovations.

A significant conceptual transformation is occurring: Louis Pasteur's popular thesis that "*There are no such things as applied sciences, only applications of science*" is evolving into the idea that *"There are no such things as science and its applications, only technoscience*." ***Technoscience is becoming the new paradigm of the future.***

4. Conclusion

According to the modern understanding, technoscience represents a synergetic teaming of science and technologies, so that the whole amounts to more than the sum of its components. It is the language and grammar we use to explain the world around us, as well as ourselves and our place in the world (Haraway 1997). Technoscience exploits the "plasticity of natural systems" that enables technological anthropogenic intervention in those systems in the form of re-engineering aimed at improving them from a human viewpoint (Andreev 2011).

In other words, technoscience is not simply a close combining of science and technologies but, beyond that, represents a symbiosis of the two that includes such social factors as attitudes, values, strivings and needs. That is why the effective functioning of technoscience is largely ensured by its in-built mechanisms for taking into account social interests and expectations, which become a significant factor determining the further development of science and technologies. As a result, the number of studies on the ethical problems of technoscience is understandably growing.

The concept of technoscience is especially relevant to integral, interdisciplinary areas, such as nanotechnologies, biotechnologies, genetic engineering, synthetic biology, informatics and cognitive science, in which it is simply impossible to distinguish the pure research aspects from the technological and applied ones. At the same time, technoscience engenders far-reaching and large-scale transformations in the environment of human habitation and in humans themselves, as objects of technological manipulation. In converging, these promising scientific-technological currents are acquiring the growing power and capacity to actualize possible scenarios that until recently were familiar only from science fiction - outcomes such as the effacement of the borderline between object and subject, between animate and inanimate, between natural phenomena and artifacts. All these are becoming true emanations of modern technoscience. Many new scientific fields are emerging as a result of the synthesis of science and high technologies, the achievements of which are resulting in the so-called radical innovations, i.e., improvements taking place on a growing scale, achieved in separate thrusts, and aimed not only at acquiring knowledge of nature and society but also at effecting powerful anthropogenic transformations of the objective world.

This makes it urgent to deal with a growing number of challenges to theory and practice of knowledge production as well as to education in science and technologies. Overall, humankind is living in an increasingly technogenic environment, which requires intensive "scientific care".

In conclusion, we may agree with Donna Haraway that "*technoscience extravagantly exceeds the distinction between science and technology as well as those between nature and society, subjects and objects, and the natural and the artificial that structured the imaginary called modernity*" (Haraway 1997, 4). To this expressive statement, I would add that technoscience also raises serious challenges to our future. However, if applied with due responsibility, it can also open enormous possibilities for the flourishing of human civilization and its accession to a new level of development.

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