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(Post)constructivism on Technoscience

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Abstract

The main aims of the article are as follows: (1) to indicate that cognition (in particular the conditions of effectiveness in laboratory practices) may be satisfactorily modelled from a (properly determined) constructivist perspective; (2) to reconstruct the latest tendencies within science and technology studies encapsulated in the term (post)constructivism rather than in the notion of social constructivism; (3) to show how technoscience is conceptualised from the (post)constructivist standpoint.

Key words: science and technology studies/sociology of scientific knowledge, (post)constructivism, technoscience, laboratory practices.

Preliminary Remarks—around Constructivism

The research aims of this article are as follows: 1) to demonstrate that cognition, including the phenomenon of effectiveness in laboratory research, may be satisfactorily modelled from a (properly determined) constructivist perspective; 2) to reconstruct and amplify the meaning of the latest tendencies in science and technology studies encapsulated in the term (post)constructivism rather than in the notion of social constructivism (this shift could be especially relevant to the context of Polish reception; 3) to show how (post)constructivism conceptualises technoscience.

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The stance taken in this article should be situated in the framework of constructivist reflection on science (including hard sciences) that has been recently developed and reconstructed in Poland (e.g. Zybertowicz 1995, 1999, Sikora 2006, Abriszewski 2008, Abriszewski & Afeltowicz 2007, 2009, Bińczyk 2004, 2010a). The paper is mainly based on Bruno Latour's actor-network theory, as well as selected theses of Andrew Pickering, Harry Collins, Steven Shapin, Karin Knorr-Cetina and Ian Hacking. The conceptions put forward by the_aforementioned authors have their roots in science and technology studies, sometimes also described as the sociology of scientific knowledge. The studies developed from the so-called *strong* programme in the sociology of scientific knowledge of the Edinburgh School in the 1970's. This interesting research area incorporates empirical case studies from the history of science and technology as well as analyses of contemporary dynamics of scientific controversies or processes involved in stabilising discoveries and innovations. Furthermore, science and technology studies encompass investigating the role of particular laboratory and experimental practices, research organization, laboratory equipment, measuring instruments, materials, samples, including the influence of tacit knowledge and the institutional aspect of scientific research.

In Polish humanities, we can distinguish several separate, characteristic ways of interpreting or projecting constructivism. Due to space restrictions, the comparison drawn in this article is rather concise and by no means exhaustive. Let us not forget, for order's sake, that alongside constructivism in (laboratory) science studies, there is also constructivism interpreted as a standpoint in sociological theory, a specific view of the society inspired by the the classic sociology of knowledge. In the latter case, it is emphasised that knowledge co-produces social structure, while collective consciousness and social order both undergo the processes of construction. *The Social Construction of Reality* (Berger & Luckmann 1983) written by Peter Berger and Thomas Luckmann is one of the key works in this trend. On the other hand, there are also constructivist themes in various cognition models inspired by the legacy of Immanuel Kant's epistemology. Such models underline the active role of the subject (language, culture, convention) in the process of cognition. The object of cognition is not given, but constructed, determined by a priori factors of different origin that condition the subject. Quite interestingly, one of the most recognised and well-developed Polish constructivist standpoints presented by Andrzej Zybertowicz in his study *Przemoc i poznanie. Studium z nieklasycznej socjologii wiedzy [Violence and cognition. A study in the nonclassical sociology of knowledge]* (Zybertowicz 1995) unites all three tendencies.

It would be a mistake to overlook yet another tendency in research that may also be adequately described as constructivist. Here, I have in mind the developments in communication studies as well as literary studies inspired by the radical constructivism of such thinkers as Ernst von Glasersfled, Heinz von Foerster, Humbert R. Maturana, Francisco J. Varela or the system theory of Niklas Luhmann. I do not feel competent enough to exhaustively describe this tendency; for more information please refer to *Konstruktywizm w badaniach literackich* (Kuźma, Madejski & Skrendo 2006, see also Kawczyński 2003)[168].

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The point of departure for the present article is that constructivism remains to be seen as an attractive and promising proposition. This concerns, in particular, actor-network theory and the tradition of science and technology studies, wherein the efficacy and professionalism of both domains (that is science and technology[169]) are promisingly elaborated upon. Still, we need to acknowledge right at the beginning that the metaphor of construction or constructing, and above all social construction, has led its interpreters astray time and time again (see Hacking 2000: 1-62). Not unlike every other metaphor or category used to build up a theory, it has numerous advantages and disadvantages that are duly exploited by its proponents. Highlighting particular features of a given domain covers others and provokes interpretations that may not have been intended by its authors.

Let us ask then what are the valuable functions of the metaphor in question? First of all, we ought to remark that "to construct" means to create and to build. Consequently, in constructivism, cognition is usually modelled as a particular practice, a kind of creative activity. Secondly, the constructivist perspective provides us with a way to conceptualise cognition as a collective undertaking. The said construction is not performed single-handedly, but requires cooperation. It is also important to note the difference between constructing as a particular process and the construct as a result of this process. For the purposes of this article, the process of constructing is of more interest (espe-

[168] Another publication *Konstruktywizm w humanistyce* (Kowalski & Pałubicka 2003) should also be mentioned; this is, however, a collection of articles on various subjects (e.g. reconstructing the conceptions of Ernest Gellner, Samuel Huntington and the question of Martin Heidegger's constructivism). Many of the articles published in the collection, the introduction included (!), do not directly concentrate on the issue of constructivism. The authors of the introduction merely note that the key problems raised in the publication, i.e. the issues of *scientificity of human sciences* and the *condition of philosophy*, are placed in the field of "widely understood constructivism", which is in passing defined as "researching the way our thoughts and activities construct the world around us".

[169] In Polish, there are two nearly synonymous terms: "technika" (technique) and "technologia" (technology); with regard to these words we can talk about a definitional confusion. Correspondingly, a similar linguistic complication occurs in English. Without engaging in terminological debates, let us assume after *What Things Do. Philosophical Reflections on Technology, Agency, and Design* that technique denotes abilities connected with producing and processing artifacts (see Verbeek 2005: 3), whereas technology denotes modern inventions, firmly based on scientific discoveries that proliferated in the 19th century.

cially in the domains of science and technology) and should be understood as building relations, stabilising them, creating links, mobilising resources. This view of constructing is interestingly close to the classic sociological notion of institutionalisation and implies a gradual undertaking, spread in time. It can, therefore, be concluded that nobody constructs in isolation; similarly, there is no private institutionalisation of anything[170].

Finally, the metaphor of construction suggests that what is created, what is constructed, cannot be found, given or ready. The results of constructing have their history, become visible in various processes and in the end stabilise. The constructivist perspective can thus be said to allow for the effects of constructing to be regarded as contingent events (which evidently locates constructivism on antiessentialist positions[171]).

Outside Social Constructivism, Starting from the Strong Programme

The status of scientific knowledge seems to be one of the most crucial questions in the debate between the supporters and the opponents of constructivism. The practical success of technology is often invoked as a significant element in the arguments that substantiate the thesis supporting the epistemological privileging of science. As it has been indicated by Richard Boyd, Hilary Putnam and many others, it would be a "miracle" to build effective technologies on the basis of false, uncertain or inadequate theories[172]. In my opinion, no reflection on science, especially contemporary science, should ignore its spectacular practical success. I believe that it should be emphasised (even more so in the context of Polish reception) that we cannot talk about this kind of negligence in the latest research in science and technology studies.

The research perspectives central to this article, the views of Latour, Hacking, Pickering and others, critically invoke the thesis of *social* construction of reality[173]. Instead of concentrating solely on the institutional dimension of science

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[170] For this reason the amusing proposition for a constructivist to deconstruct or to construct slippers under the bed put forward by Elżbieta Kałuszyńska is simply wrongly addressed; see reviews of *Przemoc i poznanie. Studium z nie-klasycznej socjologii wiedzy* (Kałuszyńska 1999).

[171] I call essentialism a philosophical view that assumes the existence and the cognitibility of essential features, i.e. objective, given, unchangeable, belonging to the nature of things. These features constitute the essence of a given object. In anti-essentialism, the essence of things is seen as historical, accidental, contigently stablised and as such these, from the traditional point of view, are no longer essences. Essentialism is often accompanied by ontological substantialism, while anti-essentialism by ontological relativism. I have written on this subject before (see Bińczyk 2007: 47-57).

[172] Putnam, quoting Boyd, writes: "[t]he positive argument is as follows: realism is the only philosophy that does not make the success of science a miracle" (Putnam 1975: 73; see also Grobler 2006: 265).

[173] See the special edition of "Science Technology & Innovation Studies" entitled *What Comes after Constructivism in Science and Technology Studies?* (Meister et al. 2006). It should be noted that

and technology, their conceptions seem to be characterised by a strong emphasis on the laboratory, practical, instrumental and experimental dimension of science, seen as a collective enterprise. The originality of the views herein presented is predicated on the attempts to model laboratory practices as *simultaneously*: 1) situated materially, guaranteeing effectiveness; 2) empirically underdetermined (which implies rejecting the bold epistemological claims of representationism); 3) institutionalised according to standards and criteria that are historically contingent (which, in turn, implies dismissing the fundamental assumptions of essentialism). Those conceptions retain particular realistic intuitions I discuss below.

Even the strong programme in the sociology of knowledge put forward by David Bloor and Barry Barnes should not be interpreted one-sidedly — as a form of *social* constructivism, *sociological* reductionism or relativism maintaining that the subcultures of scientists "created separate worlds for themselves", as it has been articulated in Polish commentaries (see for example Grobler 2006: 275, Grudka 2003: 79-80). The standpoint of the Edinburgh School has its origins in the concern for methodological correctness in the studies of cognition, science and their historical and social conditioning. The principles of the strong programme constituted the foundations of interesting empirical research. As I have pointed out beforehand, the standpoint of Barnes and Bloor is 1) naturalistic, 2) scientistic and 3) materialistic at its core (see Bińczyk 2010b). Let us give some consideration to these three elements.

As it is emphasised by its commentators and proponents, the strong programme offers a "naturalistic" reconstruction of beliefs (including scientific ones) (Nola 2008: 263-266; Barnes, Bloor & Henry 1996: 3, 173, 182]. Naturalism in this context signifies presenting explanations that come from empirical sciences (psychology, sociology, biological and cognitive sciences). When describing the phenomenon of human knowledge (including hard sciences, mathematics and logic), the British sociologists systematically avoid referring to normative, philosophical concepts, such as truthfulness and rationality. Furthermore, the proponents of the strong programme in the sociology of knowledge perceive their undertaking as a strictly scientific analysis of science itself. Bloor goes as far to dub his approach scientism and emphases the fact that the criteria of scientificity are always methodological. Scientificity is marked by compliance with particular procedures, standards, rules or, in other words, norms (Bloor 1991: 160). Methodological accuracy is guided by rules of conducting correct research, which in each field are already given and widely acknowledged. Similarly to all other rules of human activity, methodological norms are steeped in history and this is the only kind of norms we may have.

Latour and Woolgar deleted the adjective "social" from later editions of their book *Laboratory Life: The Social Construction of Scientific Facts* (Latour & Woolgar 1979).

The ideas of the Edinburgh School can also be described as materialist or realistic. The co-proponents of the strong programme describe themselves as fierce opponents of methodological idealism, a view that ignores the role of nature in the process of cognition. To them, the basis of knowledge is a causal relation between the cognizant subject and their environment. In other words, they presume the existence of "a non-verbal causative factor" in human knowledge[174]. The influence of nature on our knowledge is nevertheless empirically underdeteremined; it cannot be specified with certainty, owing to the underdetermination of scientific theory by evidence described below.

A Banalised Version of Realism

We can ascribe a certain form of trivial realism to the conceptions discussed in the paper[175]. It would mean assuming that human cognition (and activity) is taking place in a certain environment. A similar solution is put forward by Ludwik Fleck, a Polish microbiologist and researcher of science, associated with the tradition of the sociology of scientific knowledge. He states that "[d]ue to grammatical constrains, I (only) use the word >>reality<< as a necessary grammar element of the sentences on the act of cognition" (Fleck 1986: 198). The standpoints discussed in this article simply assume the existence of an environment as a certain potentiality, within which construction is taking place.

Such banal realism is accompanied by distinct a-representationalism, a view which assumes that the properties of reality cannot be unambiguously represented or defined independently of human activities, procedures or cognitive decisions. The project of representationalism is rejected as too ambitious epistemologically. A-representationalism rejects the following assumptions 1) human knowledge adequately represents reality; 2) there is only one relation of adequate representation; 3) achieving an adequate representation of knowledge to reality explains the practical success of science and technology.

A-representationalism does not signify abandoning a rather weak thesis that in our cognitive activities, and also in research practice, we strive to build models. The primary function of model building is to simulate chosen aspects of our surroundings. Manipulating models of given phenomena makes it possible to develop valuable theoretical and practical solutions that guarantee the repetitiveness of results. In science, we continuously endeavour to find connections between various elements, such as a tissue sample, test result, chemical reaction and illness. Those connections are called "networks of

[174] In other words, ">> reality<< is simply a vast and complicated sequence of non-verbalised information that we divide into groups" (Barnes & Bloor 1993: 107).

[175] I discuss banalised realism, underdetermination of laboratory practice and technoscience in two other papers (Bińczyk 2010, 2010a).

translation" or "networks of reference" in the actor-network theory of Bruno Latour; however, he assumes that building "chains of reference" is weaker than in many other traditional epistemological views. Latour rejects the very assumption that there exists an ontological "gap" between the world and its representation (he simply proposes to ignore the problem of representation). Instead, actor-network theory reconstructs the practices of model building and "chains of circulating reference" in laboratories. Those practices encompass numerous attempts to create and to sustain the whole network of scattered relations between actual elements of different kind (see Latour 1999: 24-79, Bińczyk 2007: 223-233, Abriszewski & Afeltowicz 2007, 2009). For instance, when assessing the growth of the Amazonian jungle in relation to the Brazilian savanna that would be maps, marked trees, soil samples, colour indicators, a box for comparing samples (pedocomparator), tables, drawings, chemical tests, the final scientific publication. In other research that could be chemical substances, indicators on measuring instruments, diagrams etc. Elements that model particular dependencies are connected in research practice; however, among those elements we cannot find pure Nature, nor unambiguous and final Adequate Representation.

Underdetermination of … Laboratory Practice

In order to explain the sources of a-representationalism, I refer to a well-known Duhem-Quine's thesis on the underdetermination of scientific theory by evidence. There are numerous controversies that surround the interpretation of particular motives in the philosophy of Pierre Duhem and Willard Van Orman Quine and different views on the fact whether the ideas of those philosophers of science contain assumptions of similar meaning at all (see e.g. Ariew 1984, Rzepiński 2006, 2006a)[176]. Let us, however, try to avoid (at least some) oblique statements and assume that from now we refer to the thesis on the problem of unambiguous localisation of a falsified element. Duhem wrote:

[176] Duhem-Quine's thesis quickly started to circulate in commentaries in a simplified version that synthesised two different claims. The first concerns separability, the second is a consequence of the first one and concerns falsification (Quinn 1969; Ariew 1984: 314 *passim*). The claim of separability holds that a physicist cannot test experimentally a completely isolated hypothesis. The claim of falsification holds that when falsification occurs a physicist is not able to unambiguously localise the falsified element.

In Quine's formulation, every scientific statement may be held true, as long as we accordingly reshape other areas of our knowledge (Ariew 1984: 315). In turn, according to Tomasz Rzepiński, the thesis on the underdetermination of theory by facts has two versions that concern: 1) the underdetermination of the falsification procedure 2) the underdetermination of the choice between empirically equivalent theories, namely the theories that have the same class of observational consequences (Rzepiński 2006: 285, see also Rzepiński 2006a). Only the underdetermination of the falsification procedure is of concern for the present paper.

> the physicist can never subject an isolated hypothesis to the experimental test, but only a whole group of hypotheses; when the experiment is in disagreement with his predictions, what he learns is that at least one of the hypotheses constituting this group is unacceptable and ought to be modified, but the experiment does not designate which one should be changed (Duhem 1991: 187).

In other words, the Duhem-Quine's thesis in the quoted version suggests that the falsity of an observational (categorical) sentence should not be seen as a conclusive proof of falsity of the hypothesis, as it only invalidates a conjunction of many sentences. To refute a conjunction, we do not need to renounce the hypothesis; we can invalidate one of its component sentences. The impossibility of conducting unambiguous falsification procedures inclines us to conclude that theories are underdetermined by empirical evidence. In the words of Grobler:

> any finite set of data gives rise to an infinite number of alternative hypotheses (Grobler 2006: 59).

The undertermination thesis was accepted as a result of the difficulty with unambiguous specification of the properties of reality. Specifying the features of the world always takes place in the context of human assumptions, categorisations or results from our own manipulations and interventions. Nature in itself does not have the supreme authority in disputes; human efforts are always necessary to articulate nature, e.g. in an experimental situation. An unambiguous interpretation of any experiment results entails enclosing any controversy in the community of researchers, redefining up-to-date views and stabilising relations. An unambiguous interpretation of any experimental results demands that controversies in the community of researchers must be closed, previous solutions must be redefined, and many relations must be stabilised anew. As Latour writes:

> As long as controversies are rife, Nature is never used as the final arbiter since no one knows what she is and says (Latour 1987: 97)

Not every person is authorised to speak in the name of nature itself (referring to "pure facts" or "laws of nature"), as this requires taking up the position of a nature spokesman or simply an expert.

The phenomenon of underdetermination in science takes on the shape of a certain potentiality: it allows a possibility that any finite set of empirical data could be potentially compatible with a number of alternative hypotheses (the category of infinity would be too much here — more than one hypothesis is enough). This possibility undermines the claim that our knowledge adequately represents reality[177]. Let us, however, remark that history and current scientific practice illustrate that, in fact, apart from periods of heated controversies, not many alternatives are in fact built, as there is hardly any motivation to do so. Alternative theories or research programmes are often abandoned, for example, due to the high cost of their implementation. Therefore, it seems that the processes in which alternatives are rejected seem to be one of the most interesting phenomena to analyse in science and technology studies.

According to Hacking, analysing the underdetermination of theory by evidence in the form presented so far engenders a serious problem, as it is far too specific! The underdetermination of theory by evidence refers exclusively to the logical and the theoretical dimension of science. However, one cannot fail to see that in any actual problematic situation or in any case of falsification, scientists struggle with the difficulty of underdetermination not only on the theoretical level: they may modify the theory, redesign their laboratory equipment, change its parametres or alter the interpretation of experimental data (Hacking 2000: 71-74). This "resistance" within the scientific practice may take on different forms; for instance, laboratory procedures in use or the impossibility of redesigning the equipment may_limit the results or force delivering particular ones. A similar pressure may be exerted by the unavailability of funds or the power of silently accepted methodological or philosophical premises[178]. It can be concluded that the whole scientific practice is underdetermined, not only its theoretical level.

Hacking, in his argumentation, refers to the category of *robust fit* obtained in laboratory practice. This notion is introduced by Pickering in *The Mangle of Practice* (Pickering 1995) and describes elements that have their origin in many different layers: practice, theory, experiment, instruments, calibration (physical constants). As Pickering asserts, scientists, while trying to work out

[177] Since humans have no other way to localise the facts (in the cognitive as well as in the practical dimension) than in the context of their own claims, ideas, cognitive schemes and materially situated procedures or practices, it means that epistemological conditioning always determines our ontologies. In consequence, a thesis that we construct our beliefs with regard to what is seen as objective reality in a given community may be interpreted as an ontological thesis that we construct the so-called facts. This conclusion might have been avoided, if we could unambiguously separate epistemological and ontological dimensions. Owing to a visible lack of success in this matter, science and technology studies scholars suggest rejecting the very division between ontological and epistemological questions (the latter cannot be answered anyway, as this lies outside our research procedures and cognitive frameworks).

[178] A very good example from bacteriology is provided by Fleck who shows that the rule of species unchangeability forced particular theoretical results. It was perceived as the "resistance" of reality, whereas it was an artifact of the method. Microorganisms were not bred long enough (e.i. more than 24 hours) to observe species variability, as a result such variability was not considered at all (Fleck 1986: 124–126, see also Bińczyk 2009).

those elements, negotiate and renegotiate everything on every layer. Hacking sums it up:

> The fit between theory, phenomenology[179], schematic model, and apparatus is robust when attempts to replicate an experiment go pretty smoothly" [Hacking 2000: 72]

Still, the "fitting" obtained as a result of laboratory efforts is never the only one possible (Hacking 2000: 95); therefore, it is not possible to retain the category of adequate representation of theory to reality.

While Latour supports realistic realism (Latour 1999), Pickering is in favour of realism in its banalised version that implies the existence of material "resistance" of reality. Still, the author of *The Mangle of Practice* emphasises that "the resistance of matter" in laboratory practice never determines (as an isolated factor) the final form of scientific facts or technological artifacts. The phenomenon of "resistance" in research practice is also underdetermined. Laboratory practice is a potentially open process without any a priori, definite results and it should not be seen as teleological or essentialist, since it is a process that involves shifting research aims, transforming hypotheses, and developing skills of researchers. Pickering substitutes the notion of representation with categories of adaptation, adjustability or "interactive stabilization" in its material, technical, conceptual and social dimensions[180].

Why (Post)constructivism?

Introducing (post)constructivism, a rather complicated term, may seem unnecessary to many readers, since as (it was indicated) the conceptions mentioned in the article can be included in the constructivist research on cognition. I, however, deem this idea useful for a number of reasons. Firstly, this approach makes it possible to contrast the reconstruction of science and technology studies herein presented with the current tendencies in the Polish humanities to locate these studies (and the strong programme in the sociology of knowledge) within *social* constructivism and *sociological* reductionism. Associating the views enumerated in the present paper with sociological reductionism is inaccurate, even more so after considering the latest achievements of science and technology studies as well as the evolution of actor-network theory. Secondly, this term should call attention to the specificity of the discussed views that conceptualise science above all in its practical, laboratory dimension, accounting for its material, instrumental conditioning. Thirdly, the

[179] For Hacking "phenomenology" is an interpretation of empirical data.

[180] As there is no space for further analysis, let us merely remark that a similar model of laboratory practice was built by Knorr-Cetina, the co-creator of the ethnography of laboratory (Knorr-Cetina 1983, 1995).

approaches presented should be deemed (post)constructivist, because of the theses they include: retaining realistic intuitions, accounting for the discussed above ambiguity of laboratory practice as well as exploring the issue of technoscience and its practical success[181].

In the latest developments in science and technology studies, constructing is not considered an exclusively social undertaking. The processes of constructing are rather multi-dimensional phenomena that also take place in the "material" dimension. Generally speaking, the adjective "social" may be safely omitted while talking about constructing. The examples of constructed objects may include radios, clocks, theories, political programmes, the ozone hole, frozen embryos, data banks, anthrax bacterium or viruses such as HIV (see Latour 1993: 49-50). Only after arduous processes of constructing is there a chance to assess to which ontological domain a given object belongs: depending whether it turns out to be a natural fact, a social norm, a fiction, an idea or a set of ideas.

Usually a given, constructed object is constituted by a whole network of interconnected and ontologically diverse elements. These are not only social relations, but also factors described as natural/material (non-human), normative, organizational and symbolic that are joined and stabilised in gradual processes of objectifying facts. In the case of the ozone hole, there can be chemical research, legal acts, political actions, decisions made by ordinary people while shopping, refrigerators, deodorants, new assembly lines and ideas of future generations' rights. In the case of clocks, apart from material objects called clocks, factories and repair shops, we can talk about complex networks of connections of normative and symbolic character: legal acts that introduce the division into time zones, conventions of using clocks, agreements on measuring time, organization of practices according to time, specific socialization rules etc. In the case of anthrax bacterium, described by Latour in his work *The Pasteurization of France*, the appearance of a new bacterium as an objective fact of nature is identical with modifying the sprawling spheres in which a collective functions[182]: organization of breeding farms, the politics of farmers, the interests of civilians, scientific institutions, mental habits and everyday customs of ordinary people were altered as a result of introducing the practices of hygiene (see Latour 1988).

[181] The term "postconstructivism" is also present in Western commentaries, especially with reference to actor-network theory (see e.g. Asdal 2003, Meister 2006).

[182] I use the term *collective* present in Latour's actor-network theory. The collective is more than a society, as it incorporates the dynamics of connecting people with non-human factors whose role should also be accounted for according to the French scholar. Nonhumans, meaning artifacts and wider technological systems as well as elements traditionally described as material or natural, have co-created and co-create the parameters of the world we live in.

The results of such constructing efforts may have different levels of objectivity and may even be disassembled; for example, by questioning a fact that is problematised as a result of controversy. This process could be illustrated by the example of phlogiston, ether or coloricum in physics and chemistry. The effects of construction processes are often considered real and obtain the status of unproblematic objectivity in consequence of stabilising particular relations or ending controversies. Nowadays, this seems to be the fate of the DNA chain, the HIV virus or the mad cow disease. Being subject to the process of construction does not necessarily mean that a given object is a fiction or an artifact that can be easily deconstructed. The costs of deconstructing or destabilising a given network of connections between many elements that found a particular fact are very often enormous (and depend on the extent of connections).

Of course, the constructing efforts are limited by important restrictions, such as previous, already stabilised constructions, standardised practices and interventions made beforehand. New solutions, both cognitive (facts) and practical (artifacts) usually have to be compatible with those already present. It seems important to follow the history of discoveries and innovations introduced in a collective by analysing the said specific process of rejecting alternatives, namely the cases of ignoring particular solutions. The impression of cumulativeness, purposefulness and necessity in the history of science (or technology) is amplified as a result of "erasing" our knowledge of alternative propositions that have not been accepted. When we fail to consider rejected solutions (theoretical as well as practical), we also fail to see the contingent character of human history. Automatically accepted essentialist assumptions often constitute an improbably effective cognitive blockade in this context. From the essentialist perspective, the practical and theoretical views accepted by the collective are the only possible and true ones, as these are "consistent with" the essential properties of reality itself (with its structure increasingly better described by science).

It is then no surprise that the works such as Pickering's *Constructing Quarks. A Sociological History of Particle Physics* (Pickering 1984) are fiercely criticised. We find it hard to accept a thesis that undermines the universal status of contemporary theoretical physics. In other words, we have difficulty accepting the possibility of physics without, for instance, the theory of quarks. However, in accordance with the presented version of constructivism that rejects essentialist assumptions, such a possibility should not be excluded. Still, we should remember that physics without the theory of quarks would require many previous, perhaps difficult to imagine, alternative solutions, in the history of science and technology as well as in the history of the whole collective.

Latour puts forward a rather surprising thesis that the objects that surround us, such as radios, political programmes, viruses and bacteria are both real and fabricated or constructed. This thesis underlies the originality of (post)constructivism. We easily accept that technological innovations, such as radios and cars, are constructed, whereas a thesis that facts of nature are fabricated or construed is almost always defied. According to the French sociologist, bacteria are real for a collective, because they have been constructed by demonstrating their autonomy in laboratory practice, that is to say they have been made available to the humankind due to laboratory manipulations, interventions and actions. Furthermore, bacteria are real, as they put up resistance in laboratory by interacting with other elements in a non-free way. The properties of objects constructed in laboratory practice are not entirely pliable[183].

(Post)constructivism does not support a complete freedom of construction, but merely concludes that bacteria had been "beyond the reach" of humankind (both cognitively and in the practical aspect of "coping" with them), before they were put in the sphere of human *praxis*[184]. Before this happened, bacteria had constituted a sphere of undomesticated potentiality about which we could not have had any reliable knowledge (we could only have had metaphysical beliefs). (Post)constructivism refrains from making unjustified claims and avoids deciding on the ontological status of bacteria before they were domesticated by the collective.

From the (post)constructivist standpoint, all beings incorporated in the collective have a history of their creation and proliferation; this observation concerns not only ideas or artifacts, but also such objects as atoms, bacteria or ether. Nonhumans, also known as the facts of nature, are also the results of complex efforts of gradual recognition and practical "coping with" them. The objectivity and the properties they have from our point of view (and this is the only one we have) are the effects of experimenting, closing controversies and institutionalization. Ascribing (essentialist) properties to particular objects of nature is a historically accidental process, full of dramatic twists and turns; therefore, it seems that preserving the category of essence in its traditional understanding seems unjustified from this point of view.

[183] An unambiguous localisation of those properties outside our present research procedures and theorethical frameworks seems to be impossible, as it is consequent upon the underdetermination of laboratory practice.

[184] Present in the conception of Karol Marx, the category of *praxis* describes a historically situated practice, a set of actions supported and motivated by theoretical reflection.

(Post)constructivism on "Technoscience"

Science and technology are similarly defined in (post)constructivism — as institutionalised collective practices — designed for effectiveness and efficacy, dependable on the organizational and material infrastructure of laboratory. Practically speaking, for the proponents of science and technology studies, there are no major differences between the laboratory *practices* of scientists and engineers. In both fields it is essential to increase the level of predictability and control (of phenomena). When trying to solve growing theoretical and practical problems, scientists are struggling to repeat experiments (what constitutes an important criterion of success in empirical research), whereas engineers are trying to build functioning artifacts. The homogeneous notion of technoscience has been introduced to describe both of the above-mentioned spheres, e.g. by Latour in his book *Science in Action* (Latour 1987; see also Ihde & Selinger 2003).

Many of us reasonably resist treating the intellectual work of scientist as equal to the activities of engineers and technicians in laboratories. In the philosophy of science, and in a general outlook on life, science is mainly associated with a selfless "purely" theoretical cognition — a fundamental domain wherein human rationality is made manifest (e.g. Heller 2009: 13). The representatives of sociology of scientific knowledge, however, emphasise that it is debatable to concentrate solely on the theoretical or the intellectual dimension while analysing the phenomenon of science (and in particular contemporary science). Theorising, supposed to determine the specificity of science (in opposition to technology associated with the practice of tinkering and the implementation of intellectual achievements in a machine), plays a lesser role than expected and is an altogether different process. As it can be seen in the history of science and technology, the practice of tinkering (and random experimentation) often precedes theory. Many a time repeated practical results have been obtained without understanding the laws or mechanisms that underlie them. Moreover, the role of rational discoveries of a singular, talented researcher is rather small and the philosophical attempts to find universal algorithms of a rational science have proven unsuccessful. Understanding the phenomenon of abstract thinking requires giving attention to the real context surrounding the subject: the way it is embodied or socially and materially situated. Hence in contemporary science studies theorising is conceptualised as a specific kind of situated practices: designing, articulating, ascribing, validating, expanding and comparing models that are integrated in experimental systems (see Meister et al. 2006: 89-90).

As it is demonstrated by Latour in his article "Give me a Laboratory and I will Raise the World", the practical success of technoscience is based on using the specific infrastructure of laboratory (Latour 2009). Thanks to enclosed, isolated laboratory circuits, the complexity of phenomena may be reduced, taken out of their context, sterilised, miniaturised, purified etc. In laboratories, an immensely useful and key task is performed — attempts may be repeated, errors may be committed and their cost minimised; therefore, it is usually possible to find the best solutions by experimenting. Scientists in laboratories also stabilise and capitalise their achievements in the apparatuses they design, the instruments they use, the procedures they implement and the innovations they generate. They also go into a lot of effort to standardise measures and criteria that underlie their future success.

From the perspective of (post)constructivism, non-human factors such as equipment, measuring instruments, prototypes are an inseparable element of technoscience. Nonhumans are understood as stabilised and encased achievements of previous practices that are of crucial importance in understanding the conditions of success underlying laboratory sciences. Such factors facilitate the process of standardization (e.g. in the case of procedures and practical solutions), increase the precision of technoscience and generate entirely new, broader cognitive competences.

Of course, intellectual work is an important aspect of doing science; it encapsulates defining problems, analysing terms, observing particular relations between different ideas, finding logical relations between the consequences of hypotheses. However, by focusing exclusively on theorising or on finished theories, we tend to analyse only some of the processes present in science or rather only the *results* of this broad collective enterprise. The material, cognitive and social aspects of science are merged in laboratories that make the practical success of technoscience possible (see Griere & Moffatt 2003: 308). The latest developments in cognitive sciences oblige us to significantly alter the traditional ideas of what we call "purely" theoretical thinking. For instance, enactivism (see Lakoff & Johnson 1999) or the concepts of distributed cognition[185] suggest that it is a mistake to separate theorising and practical tinkering. Defining scientific cognition as the sphere of articulated and rationalised formal operations was already too narrow for Micheal Polanyi who introduced the notion of tacit knowledge. In laboratories, the embodiment of a subject is crucial in the cases when scientific instruments or tools are incorporated by the mind into the representation of their user's bodily schema. In this way the operations or sequences of their use are integrated into body coordination structures, such as those used while driving a car, working with an electron microscope or an accelerator.

[185] For more information on distributed cognition in science and technology studies please refer to the article "Cognition: Where the Cognitive and the Social Merge" (Giere & Moffatt 2003). Among other classic texts on the subject there are a collection of articles *Parallel Distributed Processing: Explorations in the Microstructure of Cognition* (McClelland et al. 1986) and a book by Edwin Hutchins, an ethnographer, who describes the phenomena of distributed cognition in ship navigation systems (Hutchins 1995). Similar theses on the importance of "delegating" cognitive competences onto the environment are formulated by Latour (e.g. Latour 1986, 1987).

Abstract thinking remains inevitably limited without the ability to specifically "delegate" competences and cognitive processes to objects and their surroundings. As, for example, in making complicated calculations with a sheet of paper, an abacus or a set of coordinates or building a model of the DNA structure with coloured wires and balls. The processes of "extending" or "externalising" the mind into the environment are facilitated by broad cultural systems and information technologies, such as writing, drawings, tables, graphs, registers or maps, so that we can produce cognitive results of superior quality. Due to such innovations, we can observe relations, compare results and prepare more precise and longer argumentation. Complex conceptual work, mathematical or chemical calculations, are often made "outside" the mind of the researcher, using digital visualizations, building models, prototypes of machines or measuring instruments etc. (Giere & Moffat 2003: 303; Latour 1986). Quite importantly, the only stable and lasting results are those that we have learned to "externalise" into the surroundings. Such mechanisms of "externalization" are widely employed in technoscience, whose history is, in fact, the history of innovations aimed to externalise cognitive functions (see Latour 1986: 22).

Nowadays, "pure" theorising is performed in basic science, but its importance wanes in the times dominated by commercialization processes. In contemporary society, science enters the post-academic phase characterised by interdisciplinarity, a variety of actors and institutions engaged in research, and a pressure to market scientific achievements in the short run (Bucchi 2004: 134). More and more researchers are behaving like businessmen and venture capitalism determines research programmes (Bucchi 2004: 134), especially in the domains such as nanotechnology, biotechnology and microelectronics. As Massimiano Bucchi writes:

> [i]t is calculated that around 64 per cent of research world-wide is financed by companies and that almost 70 per cent of it is performed by the companies themselves (Bucchi 2004: 135).

The category of technoscience echoes the diminishing role of basic research as well as the processes of identifying research programmes with business ventures.

Instead of Conclusion: Further Inspirations

From the historical moment when the laboratory, a place of systematic experimentation, was invented, it proved to be an excellent tool for effective problem solution and capitalising scientific achievements. At the moment, as a result of the fusion of science and technology with industry, innovations generated in laboratories appear to "colonise" the collective instantly, largely thanks to market mechanisms. This incessant information exchange combined with the processes of globalization and cultural acceleration shape the dynamics of constant change in the parameters of collective life. We can observe a growing complexity, an extensiveness of relations between heterogeneous elements, along with other interesting phenomena: a radical transformation of the status of expert knowledge, a proliferation of scientific controversies, political fights for the position of defining risk. Sociologists who diagnose the condition of contemporary society, such as Ulrich Beck, Anthony Giddens, Zygmunt Bauman, Immanuel Wallerstein, and Bruno Latour, tend to write about the unwanted side-effects of modernity, new forms of risk, connected with science and technology in this context (see Bińczyk 2006). They point to new domains of systemic risk that may jeopardise the stability of a collective as a whole: ecological risk, stock market and job market risk, use of weapons of mass destruction, terrorism and epidemiological danger.

Scientific and technological interventions often have surprising consequences in areas located far away from their introduction. Sometimes such interventions may destabilise legal and economic structures, change social bonds or generate unknown ethical dilemmas. Philosophical positions that support traditional essentialism have difficulty with modelling the current range of medical and genetic interventions, the development of biotechnologies and the level of change in the ecosystems or even in the cosmic space. After all, the essentialist standpoint assumes the existence of a finished and complete reality that can be described with the use of ontologically unambiguous categories of nature and society, nature and culture, objects and humans, values and facts.

At this stage in the development of technoscience, there is every reason to ask whether our environment plays the role of unpolluted Nature, a stable background for human activity, or whether it is an artifact of our production:

> the life of a blade of grass in the Bavarian Forest ultimately comes to depend on the making and keeping of international agreements (Beck 1992: 23)

and Giddens adds:

> [w]e cannot talk about such a thing as nature, because the entire world has been changed by human technology (Giddens 2006: 3, trans. by M.W.).

It seems that, due to the level of its current transformation, nature may be described as a human construct in a trivial sense[186].

[186] Let us give two examples: the DDT pesticide accumulating in penguins living in the Antarctic and Mount Everest also known as the highest waste dump in the world with around fifty tones of rubbish.

The hybrid nature of objects introduced in the sphere of collective life by laboratories appears to justify the shift from the essentialist views. Let us take, for example, genetically modified tomatoes with jellyfish genes that glow under special light when the plants do not have enough water. Another type of genetically modified tomatoes with fish genes, the „Flavr-Savr" tomatoes, are more resistant to transportation in cold conditions (Klaasen 2007: 104-105). We need to ask ourselves the question how we should classify this type of beings.

Still another example is the practice of patenting organisms; the US Supreme Court allowed the first patent on a living organism[187]in 1980. The patent was issued for a bacterium from the pseudomonas genus designed to dissolve carbohydrates and in this way degrade oil spills. A bacterium with five thousand own genes and one added to its genome (around 0.02% change) in accordance with the court's logic became a humanmade "product", a design (see Krimsky 2003: 64). As a result of this decision, first the oncomouse was patented in 1988, then hemocytoblasts (bone marrow cells) of human foetus in 2001.

Our cognitive habits, public institutions and political procedures should be adequately equipped for the interventions made in laboratories, and in order to do this we should situate our thinking beyond essentialism. At present, (post)constructivism appears to be a suitable point of departure, as it is a good tool to model the already mentioned phenomena connected with the contemporary dynamics of technoscience. Through conceptualising cognition as a collective practice, (post)constructivism does not allow for a separation of science and technology from their integral socio-political context. Furthermore, it focuses on science itself and explores conditions conducive to its practical success, without reducing this domain to a set of theories and logical problems. By providing non-normative reconstructions of contemporary technoscientific institutions, science and technology studies offer a starting point for a reflection on the role of both domains in the contemporary world.

The constructivist perspective developed in this article allows for questioning the Enlightenment axiom of scientific independence and innocence. Furthermore, a proper reevaluation of scientific potential should be conducted without falling prey to the hysteria of antiscientism or technophobia. As Zybertowicz writes:

[187] The US Patent Office was established in 1790; it issues a patent to "[w]hoever invents or discovers any new and useful process, machine, manufacture, or composition of matter, or any new and useful improvement thereof" (35 U.S.C. 101 in: Krimsky 2003: 59).

> it should be an element of ethics in science to reject the assumption that knowledge, if verifiable, intersubjective etc., is an unproblematic good (Zybertowicz 2003: 101)[188].

Likewise, Andrzej Szahaj adds that

> the paradigm of axiological neutrality of science shows too many anomalies (Szahaj 2007: 160).

Let us hope that challenging at least some assumptions of this paradigm will initiate a reliable reflection on the political role of technoscience in the global society which, in turn, will give us a chance to openly discuss the scope of unwanted consequences of our own making.

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[188] According to this sociologist from Toruń, by introducing a constant stream of innovations and scientific validations, science generates chaos in culture. This thesis conforms to the conclusions presented above.

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