DOI: https://doi.org/10.56550/d.3.1.1		Original research article
Received on: December 27, 2023	Accepted on: September 21, 2024	Published on: October 21, 2024

Marco Buzzoni

University of Macerata
marco.buzzoni@unimc.it

OPERATIONALISM, SCIENCE AND TECHNOLOGY

Abstract

Bridgman's operationalism incurred serious difficulties, and this fact induced many authors to dismiss operationalism per se. Developed beginning in the late 1960s, Agazzi's operationalism escaped these difficulties from the beginning, but the persistence in it of a traditional primacy attributed to theory over experiment led him to pose an opposition between science and technique that was inconsistent with the general operationalist framework of his philosophy of science. Later, Agazzi sought to make his operationalism more coherent by moving toward a closer relationship between science and technology, that is, toward an intermediate solution which sees them as interacting with one another. However, in order to coherently defend an intermediate solution, it is not enough to find a certain set of properties that would be peculiar to science but not to technique, or vice versa. Rather, it is necessary to specify two distinct (but also complementary) points of view, from which science and technique can appear, at the same time but without contradiction, both as conceptually distinct and as indistinguishable as historical-empirical realities: in one sense, science is irreducible from technology, but in the other sense, they coincide completely.

Keywords: Agazzi; Bridgman; Discovery/Justification Distinction; Operationalism; Relationship between Science and Technology

OPERATIONALISMUS, WISSENSCHAFT UND TECHNOLOGIE

Zusammenfassung

Bridgmans Operationalismus stieß auf ernsthafte Schwierigkeiten, und diese Tatsache veranlasste viele Autoren, den Operationalismus per se abzulehnen. Agazzis Operationalismus, der in den späten 1960er Jahren entwickelt wurde, entging diesen Schwierigkeiten von Anfang an, aber das Festhalten an einem traditionellen

Primat der Theorie gegenüber dem Experiment führte dazu, dass er einen Gegensatz zwischen Wissenschaft und Technik aufstellte, der mit dem allgemeinen operationalistischen Rahmen seiner Wissenschaftsphilosophie nicht vereinbar war. Später versuchte Agazzi, seinen Operationalismus kohärenter zu gestalten, indem er eine engere Beziehung zwischen Wissenschaft und Technik anstrebte, d. h. eine vermittelnde Lösung, die sie als miteinander interagierend betrachtet. Um eine intermediäre Lösung kohärent zu verteidigen, reicht es jedoch nicht aus, eine bestimmte Gruppe von Eigenschaften zu finden, die der Wissenschaft, nicht aber der Technik zuzuordnen sind, oder umgekehrt. Vielmehr ist es notwendig, zwei unterschiedliche (aber auch komplementäre) Standpunkte zu spezifizieren, von denen aus Wissenschaft und Technik gleichzeitig, aber ohne Widerspruch, sowohl als begrifflich verschiedene als auch als ununterscheidbare historisch-empirische Realitäten erscheinen können: In einem Sinne ist die Wissenschaft von der Technik zu unterscheiden, aber im anderen Sinne fallen sie völlig zusammen.
Schlüsselwörter: Agazzi; Beziehung zwischen Wissenschaft und Technik, Bridgman, Entdeckungs- und Rechtfertigungszusammenhang, Operationalismus.

Introduction

Even at the cost of oversimplifying somewhat, we may distinguish three main ways of contrasting science and technology: the first, in which the so-called 'pure' sciences are opposed to their technical applications: technology would later apply the knowledge gained at first and independently from pure science; the second, which defends the independence, and perhaps superiority, of the technical mastery of certain processes with respect to their theoretical understanding; and lastly, the third, in which science and technology – similar in some respects but different in others – are in a mutual interaction.

The present paper is an attempt in the direction of the third position, which defends a relationship of unity and distinction between science and technique (or technology). Among the authors who have advocated such a position, Evandro Agazzi is of particular theoretical interest, since it is from this author's operationalist perspective that I have developed an intermediate position that diverges on some fundamental points from the one he proposed. For this reason, I shall attempt to present my views about the relationship between science and technology by moving from a critical discussion of his position.

Although, at least prima facie, the third intermediate position seems to be the most promising, it faces the serious problem of avoiding an eclecticism that would add the difficulties of the first position to those of the second (difficulties that respectively coincide with the arguments that each of the two conflicting positions asserts in favor of itself). As we shall see, this is precisely the reason why Agazzi's understanding of the relationship between science and technique (or technology) is ultimately untenable. The main thesis of this paper is that, in order to be able to consistently defend an intermediate position between those who argue for the dependence of technology on science or, conversely, of science on technology, it is necessary to distinguish between two different senses of the science/technology relationship. Only in light of this distinction, the views that need to be reconciled (and the arguments on which they respectively rest) may appear complementary rather than alternative. The distinction in question specifies two complementary and mutually dependent senses, from which science and technology may appear, at the same time but without contradiction, both identical and distinct: in one sense, science and technology are irreducible to each other, but in the other sense they coincide completely. Thanks to these different points of view, a relationship of both unity and distinction can be maintained without inconsistency. More specifically, in one sense, which I shall call genetic-methodological and that takes into account only the empirical content of the products of human knowing and acting, it is impossible to separate science and technology; in other words, and more concretely, it is impossible to find a theoretical or practical claim which would only fall under the domain of technology, but not of science (or vice versa). In this sense, science and technology are both always present in the concreteness of human knowing and doing. However, the philosophical analysis can and must distinguish science and technology in another sense, which I shall call reflexive-transcendental (taking the last term in its most usual sense; cf. e.g. Hatfield 1990, p. 79): science is the condition of the possibility of technology because, without the a priori capacity of the mind to reason counterfactually, we could not invent or devise any hypothesis and would be unable to plan the corresponding technical procedures that should test it. This is not a distinction between separate or independent fields of our culture; it is only a distinction in point of view, between two perspectives from which both human beings and all the products of their knowledge and action can be regarded and evaluated.

This paper is organized as follows. Section 2 is devoted to a critical reconstruction of Evandro Agazzi's position, where the first part compares it to Bridgman's operationalism and the second part briefly mentions Agazzi's effort to integrate technology into his own philosophy of science. In particular, I shall show that Evandro Agazzi started in the late 1960s from a rather sharp opposition between science and technique, and only later he adopted the idea of an interplay between them.[1]

In fact, his operationalist approach urged him to attenuate the primitive mainly theoreticist conception of science and, with it, the initial strong opposition between science and technology, though without ever going so far as to eliminate all inconsistency with his own operationalism. Sections 3 and 4 will critique the two most important arguments with which Evandro Agazzi distinguished, respectively, technology from science and science from technology. The result of our critical examination will be that both of these arguments are untenable. Yet, as will be shown in Section 5, Agazzi is right to try to hold together both the distinction and the unity of science and technology, but this is not consistently possible without drawing a principled distinction between the two senses of the science/technology relationship. To argue for such a distinction, I shall critically reconsider the traditional distinction between the context of discovery and the context of justification. I shall argue that it must be accepted in a reflexive-transcendental sense, which is connected with the claims of validity in general of any discourse endowed with meaning, but must be rejected in a genetic-methodological sense. This same distinction between two different meanings of the discovery/justification distinction must also be adopted to understand the relationship between science and technology. As a result, we ought to say that science and technique are and are not identical, albeit in different senses: the former assertion is true in the genetic-methodological sense, the latter in the reflexive transcendental sense.

1 As we shall see later, this is only a rough way of representing Agazzi's conception, since he distinguishes between science, technique, and technology. From my point of view, however, for reasons which will become clear subsequently, the words "technology" and "technique" may be used interchangeably, since the distinction between "technique" and "technology" is only fruitful, or even necessary, if understood as a distinction between technique and discourse on technique: it is clear that the concept of technique cannot be defined by technical means (for a use of "technique" in the broad sense here adopted, see for example Ellul (1954[1964], Engl. transl., p. 19): "[t]he technical operation includes every operation carried out in accordance with a certain method in order to attain a particular end." [...] It can be as rudimentary as splintering a flint or as complicated as programming an electronic brain."

1. Bridgman's and Agazzi's Operationalism. The Problem of the Relationship Between Science and Technology

Operationalism, in the form it takes in Bridgman's writings, incurred serious difficulties, and this fact induced many authors to dismiss operationalism per se. On the assumption that the meaning of a physical term is nothing but the operations of its measurement (cf. Bridgman 1927, p. 5), different measuring operations define different physical magnitudes so that we end up with an implausible proliferation of physical magnitudes. According to Bridgman, lengths measured with a ruler and lengths inferred from the time that light takes to travel a given distance and return are to be considered as different physical magnitudes and, strictly speaking, they should have different names: we have more than one set of operations, and therefore we have more than one concept of length. [2]

Bridgman was well aware of this consequence (cf. Bridgman 1927, p. 10), but the identity of the measurement results of lengths that are 'different' because they are measured with different instruments remains for him an unexplained accident. Why there is no one-to-one correspondence between the homogeneity of measurement results concerning, for example, 'length' and the operations leading to these results? Bridgman's conception of theoretical terms and of the very notion of scientific theory is unable to explain the unity in the multiplicity of operational procedures used to measure the same physical quantity. Because of a deficient conception of the function performed by the theoretical moment in science, this unity remains an unexplained fact of scientific research.

Agazzi's philosophy of science is decidedly operational in character yet avoids from the beginning such difficulty. Like Bridgman, Agazzi holds that scientific concepts are intimately connected with instrumental operations, but he strongly disagrees with Bridgman as to how experience and theory are to be understood.

---

2 Cf. for example Hempel 1954, 1966 (Chap. 7), Carnap 1966 (Chap. 10). Moreover, as Hempel 1966 rightly observed, there is no way of setting limits to the proliferation of concepts corresponding to the same physical magnitude (such as length), since the development of measurement instruments only slightly different from each other would lead, strictly speaking, to new and different magnitudes. The same objections have been and still are raised by many authors.

On the one hand, for Agazzi it is doing, not sense-data, that is the basis of experience. He insists on the fact that there are meaningful statements that are accepted or rejected on the basis of non-linguistic conditions, that is, of conditions which concern the sphere of "doing something" rather than that of "saying something" (cf. Agazzi 1989, p. 87). Building on Poincaré and the later Wittgenstein, Agazzi claims that people's agreement about cognitive content does not hinge on their 'private' data but on determinate actions that they perform:

> "If I have certain reasons to be doubtful about my interlocutor's having the same notion of red as mine, I could, for example, invite her to select from a bundle of pencils a red one. If the person's way of *operating* is the same as that which I should have adopted in all circumstances of this kind, I am fully justified in concluding that 'red' is an intersubjective notion for us." (Agazzi 2014, p. 76; cf. also Agazzi 1969, p. 346)

On the other hand, and more importantly for present purposes, Agazzi also differs from Bridgman in the function played by theory in the selection of any empirical quantities that we may encounter in experience and may wish to inquire into. For him, theory plays a fundamental role in shaping the cognitive object. According to Agazzi, "objects" are constituted by bundles of attributes that we single out from the specific viewpoint of any particular science. Sciences do not investigate "things" as ultimate primitive entities but consider them under different theoretical points of view, which give unity to what we intend to investigate (or measure). By considering reality from the point of view of matter, motion, and force, for example, we constitute the "objects" of mechanics rather than those of biology (cf. e.g. Agazzi 2014, p. 83 and Agazzi 1976, pp. 12-13).

In general, we can say that Agazzi's operationalism anticipated the "neo-experimentalist" turn, which in the 1980s emphasized the importance of experimenting, doing, and operating in science, but which is also true of German "methodical constructivism," recognizing the fundamental role played by theoretical mediation.[3] In this very regard, however, it is now convenient to note that in Agazzi 1969 and chronologically close works, we find a decided predominance of the theoretical and rational element over the empirical one. This is reflected in numerous topics, such as the nature

[3] For a comparison with Ian Hacking's experimentalism, see Buzzoni 2015, pp. 30-33. Among the main representatives of German 'methodical constructivism' see e.g. Lorenzen 1987; Holzkamp 1967; Mittelstraß 1974; Janich 1992 (for a comparison between Evandro Agazzi and Peter Janich, see Buzzoni 1997).

of the scientific experiment or the nature of theoretical entities (cf. on these points, Buzzoni 2015), but it finds its most important expression in the way the relationship between science and technique is conceived. On this point, Agazzi's ideas changed considerably over his philosophical career. In defining the notion of scientific theory, Agazzi 1969 took no account of its necessary connection with technical applications.[4] This remained unchanged until Agazzi 1985b, which contains, so far as I know, the first recognition of the crucial importance of technique for science.[5]

Further on, I shall examine some specific arguments that Agazzi advances to mark a difference between science and technology, but now it is rather important to note that the sharp opposition between science and technology was an internal inconsistency in Agazzi's operationalism. If one recognizes that scientific hypotheses have cognitive value only through some connection with our operational interventions on reality, then one must admit that technical reproducibility is not a criterion among many, but *the distinctive criterion of the truth of scientific propositions*. For the performance of operations in order to test a hypothesis is a technical intervention in reality. From this point of view, strictly speaking, technical applicability does not depend on theoretical truth ascertained by other means: even though truth–in a sense that we shall better clarify later–is not identical *in every sense* with technical applicability, reproducible technical applications are, in the experimental sciences, the only way of ascertaining and justifying the truth of a theory (cf. Buzzoni 1982, Chap. 3, § 4, above all pp. 190-192, and Buzzoni 1995, pp. 85-99, and 2008, Chap. 1).

It is therefore no coincidence that, from around the mid-1980s onwards, Agazzi devoted more and more attention to the connection between science and technique (or technology). A detailed discussion can be found both in *Right, Wrong and Science: The Ethical Dimensions of the Techno-scientific Enterprise* (Agazzi 1992[2004]) and in *Scientific Objectivity and Its Contexts* (Agazzi 2014). In one passage of *Right, Wrong and Science,* Agazzi went so far as to admit that, if we take into account the fact that the collection of operations that "cut out" a given field of objects from reality "constitutes a network of *techniques* (that is, a knowledge of how to do or to work) whose

[4] Cf. Agazzi 1969, pp. 36-37, 155-168, 372; see also Agazzi 1978, e.g. p. 23.

[5] That Agazzi 1985b is the first recognition of the crucial importance of technique for science is also indirectly suggested by the fact that in Agazzi 1985a the technical applications of Newtonian physics are still regarded as a simple consequence of a theoretical truth ascertained by other means (cf. Agazzi 1985a, p. 69).

goal is to make pure research possible" (Agazzi 1992[2004], p. 184, Engl. transl., p. 135), then "technique is 'consubstantial' with science itself [*la tecnica è 'consustanziale' alla stessa scienza*]" (Agazzi 1992[2004], p. 185 of the Italian edition; my translation, since there is no corresponding passage in the English edition). However, the last quoted sentence is left out in the English edition, and this omission is no accident. The claim of an intimate connection between science and technique was not consistent with the rest of the book, where Agazzi insisted that science and technique are different in principle. Technique consists only in "a *knowing how* (one does certain things), without necessarily implying a *knowing why* (they are done that way)": the efficacy and success of those actions emerge "empirically, that is in the concreteness of practice, without one being able (or at least without having to be able) to give the *reasons* or the explanation of their success". Unlike technique, science is different from other kinds of knowledge "precisely insofar as it proposes to *explain* empirical facts, suggesting reasons that tell us *why* these are in a certain way"[6].

According to Agazzi, the historical reconstruction of the relationship between science and technology also supports this conclusion:

> "many cultures have existed that developed an advanced technique in the absence of a significant science, but even in those cultures (such as the Western culture) in which science has been powerfully promoted, it is possible to write a history of technique quite independently of the history of science, since even today there are sectors in which technical skills and know-how progress according to an internal empirical dynamics and accumulation of successful practices without one really knowing why they are successful." (Agazzi 2014, p. 307)

Agazzi 2014 distinguishes between science, technique, and technology and points out that they have become autonomous systems which influence one another. According to Agazzi's "systemic perspective" or "systems-theoretic approach, every system (scientific, technological, economic, industrial, political, military, administrative, educational, legal, and so on) tends to achieve the maximum increase in the values of its essential variables

6 Agazzi 1992[2004], pp. 75-76 of the Italian edition. My translation; here too I could not find any exact corresponding passage in the English edition, but in this case, a very similar idea is to be found on p. 56, where technique or technics are distinguished from "technology": "technique is essentially the competent application of a certain *know-how* attained through the accumulation and transmission of concrete *experience* (which also entails a careful performance of acts), without necessarily being accompanied or supported by a knowing *why* such concrete procedures are especially efficacious."

compatible with a satisfactory functioning of society as a whole. While technique is the characteristic of the human species whereby it adapts the external environment to itself, instead of adapting itself to the environment (as other species do), “a new branch grows on the old science-independent trunk of technique, this is technology, which aims at pursuing the traditional goals of technique by applying scientific knowledge” (cf. Agazzi 2014, p. 307; see also Agazzi 2008, p. 41). This constituted a kind of ‘reciprocation’ that technology offered to science in response to the fact that technology itself has been able to constitute itself as such (as opposed to mere technique) insofar as it rested on the knowledge acquired by science: for this reason, it is possible to characterize technology fundamentally as “applied science” (Agazzi 2014, p. 307; see also Agazzi 2008, pp. 213-214). As a result, a positive feedback loop has been established between the scientific and technological systems, increasing their influence to the point that today we often speak of a techno-scientific system (Agazzi 2014, pp. 306 and 425-426).

From this, it is clear that Agazzi leans toward an intermediate solution, according to which a mutual interaction, correction, and/or integration between science, technology, and technique takes place (for a similar position, see e.g. Jonas 1979, p. 37; Nordmann 2006, p. 120; Niiniluoto 2016, pp. 93 e 98-99). But the main problem with this viewpoint is that, on closer inspection, it implicitly presupposes both a conceptual and real historical separation between science, technique, and/or technology. It tacitly assumes that science and technique (or technology) are, in principle, both epistemically and historically, different and autonomous entities, each of which could exist largely apart from its relation to the other. In fact, the very concept of mutual interaction assumes that some important differences exist between science and technology.

Thus, the question arises as to what significant differences exist, according to Agazzi, between the scientific, the technical, and the technological systems. To answer this question, in the following two sections, I shall focus on the arguments that Agazzi provided to support the autonomy of technique (and/or technology) from the scientific system and the autonomy of the scientific system from technical/technological systems. As we shall see in the last part of this article, although these arguments are in themselves untenable, the distinctions they support can be somewhat recovered in the form of a fundamental distinction between two senses in which science and technique (and/or technology) can be viewed.

2. Autonomy of Technology from the Natural Sciences?

As already mentioned at the beginning of this paper, it may be useful to distinguish two ways of contrasting science and technique. On the one hand, there are those who regard science itself as a consequence of technique and see the latter as the true foundation of the former. On the other hand, there are those who, on the contrary, consider technique (or technology, as already seen in the case of Agazzi) as the simple application of proper scientific knowledge. On one side, in short, are those who make natural science in the last analysis dependent on technique, while on the other side are those who make technique and/or technology in the last analysis dependent on natural science.

In this and the next section, I shall discuss these two ways of contrasting science and technology by critically examining the corresponding arguments developed by Evandro Agazzi.[7] As we shall see, these arguments fail to demonstrate either the autonomy of technique (and a fortiori technology) to scientific knowledge or of the latter to the former.

Let us begin with the argument in support of the first position, which seeks to separate science and technology on the basis of the alleged autonomy or even independence of technique from scientific knowledge. We have already mentioned this problem: Agazzi points out that science and technique are different and mutually autonomous because they could grow and develop by following separate paths, as would be shown by the fact that there have existed civilizations that were technically highly evolved but had poor science (and vice versa) (Agazzi 2014, p. 307; see also Agazzi 1992[2004], p. 76 of the Italian edition, but with no exact correspondence in the English translation). More specifically, Agazzi notes that the steam engine, a "result of ingenious inventions and exquisitely technical refinements", "did not make use of theoretical knowledge except to a very marginal extent." (Agazzi 2008, p. 50; s. also pp. 53-54)

According to this argument, of which there are several variants by different authors, technical or technological sciences would develop on their own, raising and solving new problems apart from any significant relationship to the theoretical or pure part of natural sciences. In this connection, many authors remarked that there are processes which, though not yet

[7] For a more detailed analysis of the arguments that can be made in favor of different ways of contrasting science and technology, see Buzzoni 2021.

mastered theoretically (such as combustion in internal combustion and jet engines), are mastered and applied technically, that is, even in the absence of a corresponding theory. This point, already made by Redtenbacher (1848, pp. v-vi), has been taken up by many authors. As for example Rumpf noted, the "technical sciences," far from developing the knowledge of the natural sciences only in the sense of applying it in the way a recipe is applied, would be able to lead to new discoveries on their own (Rumpf 1973, p. 96; see also Lenk 1982, p. 50; Erlach 2001, p. 20; Nordmann 2006; Houkes 2009; Boon 2011).

Now, against this argument, intended to support the autonomy, or even independence, of technique (or technology) to science, it can be noted that it is not conclusive. The fact that technique can raise challenges to science and independently answer questions that science had not even asked does not prove the irreducibility of technique to science. The argument does not rule out the possibility that, if technique exerts a decisive effect on many scientific discoveries, this might be because the two are intrinsically connected: technique might stimulate and raise new challenges for science simply because its epistemological connection with the theoretical-scientific moment can never be totally severed. And this applies not only to the so-called 'technical sciences' such as engineering but to every technique, even that closest to everyday routine.

Having rejected the argument of the autonomy or independence of technique from scientific knowledge, we must now turn to another argument, which also defends the difference between science and technique, but starting from the opposite side, that is, aiming to show that pure science is autonomous and, in the last analysis, independent of technique.

3. Autonomy of Natural Sciences from Technology?

According to Agazzi, a "fundamental aspect" of Galilean science has always been to provide a form of knowledge that can indicate not only *how* but also *why* things are the way they are. In other words, typical of science would be the fact of raising, with respect to technique, the properly cognitive question of why. With this argument, Agazzi takes up perhaps the most traditional view regarding science and technology, namely that the natural sciences, implicitly or explicitly, can grasp reality independently of technique. In a passage already partly quoted in Section 2, he writes:

> "Technique can be considered, in a broad sense, as an accumulation of operational procedures, useful from a practical point of view for achieving particular ends. They are usually discovered, tested and improved upon through the experience of many generations and constitute a *knowing how* (one does certain things), without necessarily implying a *knowing why* (one does them that way), in the sense that their efficacy and success emerge empirically, i.e. in the concrete of practice, without one being able (or at least without having to be able) to give the *reasons* or the whys of their success."[8]

Now, such a principled distinction between technology and science is not sustainable. Ancient technology also presupposed empirical knowledge around the world, only, from our point of view, it was full of unclarified assumptions. *Technical intervention in the world, insofar as it is not a blind and strictly speaking a properly nonhuman intervention, must possess to some degree the reasons for its doing*: a technique entirely separated from an explanatory moment would no longer be a *human* technique. It is impossible for man to practice technique without at the same time, more or less implicitly, practicing science, in the sense of posing problems and offering answers that at the same time, consciously or unconsciously, have cognitive or explanatory character.

Second, and most important, the distinction between knowing 'how' and knowing 'why' can only be understood as a functional one, not a substantial one. What counts as 'knowing why' at a certain cognitive level appears as a 'knowing how' at a further level where deeper questions arise; this deeper questioning changes the previous 'knowing why' into a given (a 'knowing how') in need of further explanation. For example, one could think that we only have a 'knowing how' about the functioning of the more common household appliances; but what is *prima facie* a 'knowing how' (say, that the dishwasher is turned on by pushing a certain button, with no deeper knowledge of its functioning) for a child may well be a 'knowing why'. To the child's question *why* the dishwasher has started making that noise, we may reply, for instance, that this happens just 'because' we pushed a certain button which turns it on. Likewise, we can distinguish between our knowledge 'that' the dishwasher does not work and the technician's knowledge of

---

[8] Cf. Agazzi 1992[2004], pp. 75-76 (my translation; as already mentioned in footnote 7, the English translation contains no exact correspondence with the original text, although a very similar idea is found on p. 56). For a similar argument see e.g. Blumenberg 1953, p. 119, according to which the question of "how" is the "primary technical question", or Erlach 2001, pp. 14–15. More cautiously formulated but similar is Rapp's definition (1978, pp. 69–71).

'why' that is the case (say, 'because the condenser is broken'). However, the technician's 'knowing why' is, from the point of view, say, of an electrical engineer, a 'knowing how' which in turn calls for an explanation as to 'why' the condenser is broken – and so on without end, at least in the sense that it is not possible to establish a frontier beyond which science can progress no more.

One could respond by adducing *prima facie* more convincing examples of mere 'knowing how'. Many technical improvements proceed from chance (or serendipitous) discoveries and can further improve without probing the reasons behind these improvements. For example, if an angler all of a sudden caught many more fish than usual and noticed that the hook had been accidentally bent for some unknown reason, from then on, that angler may always use that hook and may also bend it more or in different ways actually producing more efficient hooks.

At first, it would appear that the angler has no insight into the reasons for his undeniably technical behavior. But if we look at the example more closely, it soon becomes evident that this is not the case. The angler would have never embarked on the search for more efficient hooks had he not noticed that the hook worked better *because it had been bent*; and this is a knowing 'why', it does not matter at how elementary or low a degree. Without this *explanatory* hypothesis, the angler would not have progressed to using the bent hook systematically, let alone to improving on it technically. In the course of the historical development of scientific knowledge, a division of labor developed between those who operate in the field of basic science and those who operate in the applied sector; but this does not call into question the fact that science can know only by acting and intervening technically in reality, and that this intervention, in so far as it is not blind but has some access to its reasons, is from the very beginning to some degree scientific.

From this point of view, as already mentioned, also the distinction between 'technique' and 'technology' is legitimate in only one of its senses, namely as the distinction between technique and discourse on technique: the concept of technique cannot be defined by technical means. For Agazzi, technology is an "efficient" operating that "is conscious of the reasons for its efficacy and is based upon them, that is, where operation is nourished by its grounding in *theoretical knowledge*"[9], while technique is a pure 'knowing how to do' lacking knowledge of the reasons of this doing. But although intended to separate in principle technology from technique, this in actual

[9] Agazzi 1992[2004], p. 77, Engl. transl., p. 57.

fact only separates human from animal technique. In the human sphere, the distinction is only one in degree: all 'knowing how to do', even in the weak forms of habit and/or compulsion to repeat, *qua* knowing, involves at no matter how infinitesimal a level a noetic aspect of critical awareness. Certainly, animals too interpret their environment and thereby use something similar to our concepts, but (with all the caution due when talking about animal capacities) these 'concepts' probably lack the human prerogative of criticality, that essential openness that lets them be freely modified according to the changing of situations.

It is surely legitimate to distinguish between a scientific-theoretical attitude that concerns itself with the way things are (the search for truth) and a practical-technical attitude that aims at transforming things according to certain concepts or values. However, this is quite irrelevant to our problem, namely the epistemological relationship between science and technique. In particular, this does undermine the fact that one can know empirical reality only by acting and intervening in nature and that one can act on nature only by means of concepts, without which acts would be no more than chance events.

Now, since we have concluded that the two main arguments for the claim that there is a clear-cut distinction between science, technique, and technology are flawed, should we be inclined to accept that they are, in the last analysis, the same thing? As we shall see, the answer is "yes and no": yes, in the sense in which we have been arguing so far, and which is still to be investigated in its epistemological status. No, if the relation between science and technology is taken in a sense that we have not yet considered, and which will be introduced in the next section. As we anticipated, this paper intends to defend an intermediate position between those who argue for the dependence of technology on science or, conversely, of science on technology. My positive thesis will be that, if we distinguish between two senses of the discovery/justification dichotomy, the correlative distinction and unity of science and technology may be coherently defended. As we shall argue, science and technology are and are not identical, though in two different senses. But in order to defend this thesis, we require a brief *détour*: a critical analysis of the well-known distinction between the context of discovery and the context of justification. In the next section, I shall make two points: 1) that there are two senses in which we may understand the relationship between discovery and justification, and 2) that the distinction in question must be retained in one sense and rejected in the other. Both points will be necessary to make the third decisive point in Section 6: on this basis, we shall argue that what we are going to say about discovery and justification is also true of the relationship between science and technique. It is necessary to distinguish two senses in which this relationship can be understood: in one sense science and technique are identical, in another, it is possible to draw a sharp line between them, in spite of the fact that there is no scientific sentence that, in principle, could not be expressed (and possibly realized) in technical terms.

4. The Context of Discovery Versus the Context of Justification

The distinction between the context of discovery and the context of justification runs with different names through all philosophy of science since its beginnings at the end of the nineteenth century, but takes on particular importance and becomes almost a philosophical commonplace in logical empiricism and Popper. Generally speaking, logical empiricists and Popper used the distinction between the context of discovery and the context of justification to grant empirical science cognitive autonomy from its cultural and historical context.[10] But this was precisely one of the main reasons why exponents of the “relativist turn” in the philosophy of science of the 1960s (notably Kuhn and Feyerabend) and proponents of the sociological turn since the 1980s (notably Bloor and Latour) have rejected the distinction in question.

Now, in what sense and to what extent was this refusal justified? This rejection was certainly not justified insofar as it emptied the expression ‘truth’ of all meaning, as can be seen from the main argument used in its favor. According to Kuhn and Feyerabend, in particular, for merely playing a historical-causal role in advancing science in the way it has progressed to its present state, *empirical-historical factors* such as scientists’ prejudices and personal

[10] For historical and conceptual details on the distinction between the “context of discovery” and the “context of justification”, see Schickore and Steinle (eds) 2006 (above all Part I and Part II), Hoyningen-Huene 1987, and Buzzoni 2015. Hoyningen-Huene 1987 carefully analyzes several senses of the discovery/justification distinction, but while these distinctions are certainly useful in particular contexts, none of them coincides with the one I have developed since Buzzoni 1982, and which is essential to defending the unity and distinction between science and technique (or technology) in the sense of the central thesis of this paper.

idiosyncrasies, aesthetic preferences, religious beliefs, etc., are to be put on a par with more traditional *reasons* for maintaining or rejecting a theory, such as coherence, explanatory scope, unifying power, etc.[11]

In other words, merely because they played a historical-causal role in the scientific process, factors such as scientists' prejudices and personal idiosyncrasies, aesthetic preferences, religious beliefs, etc. (such as, for instance, Kepler's worship of the Sun God), are put on a par with a theory's explanatory power or its ability to solve more problems than previous theories. However, on reflection, to ascribe *in principle* the same epistemic and argumentative weight to psychological, sociological, and, in general, empirical elements as to representational ones *just because historically they play a causal role in the advancement of scientific progress,* presupposes that human concepts are entirely determined and explained by real historical circumstances.

This, of course, is the core thesis of relativistic historicism, and it means that, apart from the positive level (of psychology, history, sociology, etc.), there is no qualitatively different level from which one might evaluate the truth or falsity of competing conceptions. Thus, the baby had been thrown out with the bath water. The baby was the minimal sense, which I shall call *reflexive-transcendental*, in which reason is irreducible to empirical, particular causal factors, namely as an expression of its claim to represent, in principle, things as they really are (no matter how far this can succeed). Although a countless number of physical, biological, psychological, sociological, and, generally, contingent or accidental factors influence and limit human reason, the irreducibility of this latter, at least in an important sense, cannot be denied without denying all possibility of meaningful thinking or talking. Any claim to reduce reason to causal factors, necessarily presupposing its own truth, is irreducible to the causal factors to which, contradictorily, it grants a determining power over itself. In fact, to assert any empirical fact is to assert, implicitly, the distinction in principle between reason and facts, without which there would be neither one's own asserting nor one's own denying.

At least in this (reflexive-transcendental) sense, the distinction between the contexts of justification and discovery is constitutive of reason and cannot be denied without contradiction since it is affirmed by the very act of negating it. However, it is necessary to distinguish at least one other sense, which has already emerged in some of the previous considerations and

---

11 Cf. Feyerabend 1970, § 14; Kuhn 1962, pp. 151-156; for typical exponents of the sociological turn, see e.g. Bloor 1991, pp. 36–37 and Knorr Cetina 1992, p. 116.

which I shall call *genetic-methodological*, which is the opposite complementary of the reflexive-transcendental just seen, and in which the discovery/justification distinction must be rejected.

The reflexive-transcendental claim to represent, *in principle*, things as they really are, by itself is not enough to justify us in accepting any particular empirical claim or theory. For this reason, strictly speaking, it is in itself devoid of any particular, or empirically detectable, content. Therefore, the crucial question becomes: How can this claim be concretely realized in particular situations? The answer is that, if the general claim of representing things as they are is not to remain devoid of any particular content and cognitive function, it must be realized by means of concrete methodological procedures which make it possible to reconstruct, to re-appropriate, and to evaluate in the first person the reasons why a particular truth-claim should be accepted. In other words, the truth-claim of our discourses tends by its very nature to translate (in principle without residue) into particular methods (or techniques).

Not only the logical empiricists Popper and Lakatos but also the exponents of the sociological turn, failed to clearly identify this sense, in which a genetic-methodological attitude is decisive for justification. To test the truth value of a statement, in principle we must always adopt a genetic and historical-reconstructive attitude and retrace the main methodological steps taken by those who first achieved a certain result through those steps. Pythagoras's Theorem can be used in a practical way without recalling the procedural steps of its demonstration. But if someone challenged its validity, we ought to test it by retracing in the first person the methodological-procedural steps that led to that theorem being asserted. By doing this, we *justify* a theory by historically reconstructing the context of its *discovery*. In this sense, the context of discovery and the context of justification are one and the same thing (for a more detailed justification of this thesis, see Buzzoni 2008 (ch. 1, §§ 4-7) and 2015; for its first formulation, see Buzzoni 1982, Ch. 3, especially Section 1).

Now this unity and distinction between a reflexive-transcendental and a genetic-methodological sense of reason entails, among others, a decisive consequence for the relationship between science and technology, to which the last part of this paper is devoted.

5. The Two Senses of the Relationship between Science and Technology

At this point, we have developed all the necessary premises to deduce the main thesis of this paper. Let's stop for a moment and take a look at the road traveled so far. In the first part of this paper, we discussed and rejected the two main arguments aimed at separating science and technology, that is, aimed at conceiving of science and technology as two fields of human culture that might exist side by side, that are in principle mutual autonomous, and that therefore only in fact interact with each other. In the second part, we discussed the fundamental distinction between the context of discovery and the context of justification. We saw that the distinction between these two contexts must be accepted in one sense (which I called reflexive-transcendental, connected to the truth claims of any discourse endowed with meaning), but rejected in another sense (which I called genetic-methodological).

For the purposes of our problem, it is decisive to remember that these two senses are indeed distinct, but also complementary and intrinsically connected with each other in the concreteness of our knowing and acting. As we said earlier, if the claim to represent things as they are is not to remain devoid of actual cognitive results, it must express itself through concrete methodical procedures, necessary for both every actual appropriation of cognitive content and every concrete practical action. From this, we may derive the main conclusion of this paper. Indeed, we are now in a position to infer, while avoiding the path followed by eclectic and ultimately internally contradictory solutions, that between science and technique, there is a relationship of unity and distinction *in two distinct but interconnected and complementary senses.* On the one hand, in the sense I have called reflexive-transcendental, we can and should distinguish science and technology. As our previous discussion around the discovery/justification distinction has shown, in the reflexive-transcendental sense the theoretical-conceptual claims of science are irreducible to the technical procedures put in place for their ascertainment (or for their verification, confirmation, etc., depending on the different conceptions to which one adheres). In this sense, science is the condition of possibility of technique, for without our mind's a priori ability to reason counterfactually, we could not invent or devise any hypothesis and would be incapable of designing the corresponding technical procedures necessary to check it (verify it, confirm it, etc.). Only in the reflexive-transcendental perspective, theoretical and methodological aspects may be separated by counterfactual reasoning, in the light of which the theoretical aspects appear as the conditions of possibility of the technical ones. On the contrary, in the concreteness of practicing science they are inseparable: 'science' is the condition of the possibility of the knowledge of determinate aspects of reality in so far as it allows one to regard *as possible* causal-technical connections that, so far as their contents are concerned, must be translatable, in principle without residue, into successful technical applications.

For this reason, truth is plainly not the same thing as technical usability, just as a theory is not merely an instrument, and yet a theory, insofar as it is true and affords us to know how things actually are, must also potentially be useful: we can prove that a theory says something true about the world only by showing that it can be translated into operationally, technically reproducible results. The technical aspect has a truth-value only in so far as it translates into actions a conceptual mediation without which the technical aspect would appear isolated from any causal context – that is, as a mere coincidence, a chance event not reproducible outside the precise and punctual situation in which it occurs (this is perhaps the case when animals use tools). The theoretical-conceptual claim (or, which is the same, the scientific claim) to represent things as they really are, is concretely realized in the empirical sciences by means of specific technical-experimental procedures of ascertainment (whether physical, chemical, historical, sociological, etc.). In the scientific experiment, a nexus between propositions, which is a properly theoretical content, is exemplified in the operation, in an important sense independent of the personal subject, of a technical apparatus in which what I call the "experimental machine" properly consists. In the scientific experiment, the operation of an experimental machine exemplifies a nomic connection that exists in nature: after triggering a certain technical process, it unfolds in a manner completely independent of us, concretely demonstrating the existence in nature of a connection that is certainly dependent on us with respect to its conceptualization, but which is completely independent of us with respect to its actual content.

It is important to stress this point: technical applicability cannot depend on theoretical truth ascertained by other means: even though truth is not identical *in every sense* with technical applicability, reproducible technical applications are, in the experimental natural sciences, the only way of ascertaining and justifying the truth of a theory. Attempts at separating 'pure' science from its technical applications are doomed: it is impossible to draw an epistemological, non-arbitrary distinction in principle between the use of technical-operational procedures in the empirical sciences, and their use for exclusively practical ends. From a strictly epistemological point of view, the use of radio waves for practical purposes was a decisive reason for the truth of the electromagnetic theory. Similarly, the explosion of the first atomic bomb provided a terrible confirmation of Einstein's equation, expressing the convertibility between matter and energy.

In this sense, which I have called genetic-methodological and which considers only the empirical content of every possible product of human activity (which, let it be noted in passing, is what we properly may call "nature"), it is impossible to separate the technical content of scientific knowledge from the theoretical-conceptual content of human technique (and vice versa). In this sense, insofar as we are dealing in both cases with two universal aspects of human knowing and acting, it is impossible to empirically draw a boundary between science and technique. They, in concrete situations, are always found together, and it is impossible to find a theoretical or practical statement that would fall under the domain of technique alone, but not under that of science (or vice versa). In the methodological perspective, in short, the extensions of science and technique completely coincide.

The thesis of identity between science and technology, which is in general a minority opinion, is relatively frequent in the science-technology studies, where it is often accompanied by the term "technoscience", originally coined by Gaston Bachelard and successfully revived by Bruno Latour. Barnes, one of the leading exponents of the sociology of scientific knowledge, writes:

> "We recognize science and technology to be on a par with each other. Both sets of practitioners creatively extend and develop their existing culture; but both also take up and exploit some part of the culture of the other [...]. They are in fact enmeshed in a symbiotic relationship."[12]

As we have seen, however, this is true in one sense, the genetic-methodological one, but not in all its generality, since it simply ignores the reflexive-transcendental aspect as an irreducible condition of possibility of the historical-methodological realization of science. In general, it is important to reiterate once again that the distinction between a reflexive-transcendental

[12] Barnes 1982, p. 166; see also Pinch and Bijker 1984, p. 404. In a similar vein, Martin Carrier argues that this identity is true at least in regard to contemporary science, where technology and science tend to coincide with one another because the scientific objects are not the things in nature, but – following Bachelard's notion of "phénoménotechnique" – the technological artifacts (cf. Carrier 2011, p. 44).

sense and a genetic-methodological sense of the science/technology relationship is not present in the reality of things, and it does not hold between autonomous or independent fields of human culture, fields that occupy a different space and a time; it is only a distinction that results from a mental act of counterfactual abstraction, which holds between two perspectives from which both human beings and the products of their knowing and acting can be considered and evaluated.[13]

Conclusion

As I have shown in the first part of this paper, Agazzi's conception of the relationship between science and technology is representative of a fairly widespread tendency in the literature on the subject, which assumes that science and technology, while sharing some similar aspects, are distinct from each other in some other respect, so that they are two autonomous entities that interact with each other. However, the two main arguments aimed at proving this thesis have some fundamental flaws: firstly, they are not conclusive and thus fail to demonstrate the principled distinction between science and technology; secondly, and most importantly, they assume that science and technology are autonomous systems, historically concrete and identifiable realities that act on each other, whereas in the methodological concreteness of scientific knowledge theory must always be present at the same time as technique, and vice versa.

However, Agazzi does not err in seeking an intermediate view between those who tend to separate science and technique and those who, on the contrary, tend to identify them completely. But in order to develop this intermediate position without falling into eclectic solutions, exposed to the objections that the conflicting views address to each other, it is necessary to draw a distinction between two fundamental senses in which the nexus between science and technique can be understood. Between science and technique, there is a principled distinction only in the sense I have called reflexive-transcendental. Only in this sense are the theoretical-conceptual claims of science not reducible to the technical procedures necessary for

[13] It should be noted in passing that this point, although seemingly abstract, has concrete consequences for maximizing the control we have over technology and, conversely, for minimizing the control that the products of technology - because of the way they are designed and the values they inevitably embody - exert over human persons. On this consequence, for reasons of space, I must refer to Buzzoni 2020.

their ascertainment. But this sense is not only compatible with, rather it requires as a complement the sense I have called genetic-methodological, according to which the scientific system and the technical or technological system completely coincide because they are the two inseparable moments of the same practical-cognitive act. In other words, there are not two independent enterprises, science and technology, but one, with two complementary and mutually dependent sides, one reflexive-transcendental, the other genetic-methodological.

References

- Agazzi E. 1969. *Temi e problemi di filosofia della fisica*. Abete, Rom.
- Agazzi E. 1976. Criteri epistemologici fondamentali delle discipline psicologiche. In G. Siri (ed), *Problemi epistemologici della psicologia*, pp. 3-35. Vita e Pensiero, Milan.
- Agazzi E. 1978. Les critères sémantiques pour la constitution de l'objet scientifique. In: M. Bunge (ed), La sémantique dans les sciences. pp. 13-29. Beauchesne, Paris.
- Agazzi E. 1985a. Commensurability, Incommensurability, and Cumulativity in Scientific Knowledge. *Erkenntnis* 22, 51-77.
- Agazzi E. 1985b. Gli strumenti e l'oggettività scientifica. *Epistemologia. An Italian Journal for the Philosophy of Science* 8, 3-14.
- Agazzi E. 1989. Naive Realism and Naive Antirealism. *Dialectica* 43, pp. 83-98.
- Agazzi E. 1992[2004]. *Il bene, il male e la scienza*. Milan: Rusconi. English edition: Agazzi, E. 2004. *Right, Wrong and Science: The Ethical Dimensions of the Techno-scientific Enterprise*, ed. by C. Dilworth. Rodopi, Amsterdam/New York.
- Agazzi E. 2008. Le rivoluzioni scientifiche e il mondo moderno, Fondazione Achille e Giulia Boroli, Novara.
- Agazzi E. 2014. *Scientific Objectivity and Its Contexts*. Springer, Heidelberg/New York/Dordrecht/London.
- Barnes B. 1982. The Science-Technology Relationship: A Model and a Query. Social Studies of Science 12, pp. 166-172.
- Bloor D. 1991. Knowledge and social imagery. Routledge and Kegan Paul, London (2nd edition).

- Boon M 2011. In Defense of Engineering scienze: On the Epistemological Relations Between scienza and Technology. Techne 15, pp. 49-71.
- Bridgman P.W. 1927. The Logic of Modern Physics. MacMillan, New York.
- Buzzoni M. 1982. Conoscenza e realtà in Karl R. Popper, Angeli, Milan.
- Buzzoni M. 1995. Scienza e tecnica. Teoria ed esperienza nelle scienze della natura. Studium, Rom.
- Buzzoni M. 2008. Thought Experiment in the Natural Sciences. An Operational and Reflexive-Trascendental Conception, Königshausen+Neumann, Würzburg.
- Buzzoni M. 2015. Science and Operationality. In: Alai M., Buzzoni M. and Tarozzi G. (eds.), Science Between Truth and Ethical Responsibility, pp. 27-44. Springer, Cham.
- Buzzoni M. 2020. Is Technology an Autonomous Process? Technology, Scientific Experiment, and Human Person. Axiomathes 30(6), pp. 629-648.
- Buzzoni M. 2021. How not to Distinguish Between Science and Technology. Diogenes. Journal of the Department of Philosophy. Faculty of Arts. Cairo University 1, pp. 35-58.
- Carnap R. 1966. *Philosophical Foundations of Physics*. Basic Books, New York.
- Carrier M. 2011. "Knowledge is Power", or How to Capture the Relationship between Science and Technoscience. In A. Nordmann, H. Radder & G. Schiemann (eds.). Science transformed? Debating claims of an epochal break, pp. 43-53. Pittsburgh University Press, Pittsburgh.
- Ellul J. 1954[1964]. La Technique ou l'enjeu du siècle, Colin, Paris. Quotations are from the English Translation, The Technological System. Knopf, New York.
- Erlach K. 2001. Eine Kritik der poiëtischen Vernunft, The Journal for General Philosophy of Science, 32, pp. 1-25.
- Feyerabend P.K. 1970. Against method: Outline of an Anarchistic Theory of Knowledge. In: M. Radner and S. Winokur (eds.), Analyses of Theories and Methods of Physics and Psychology, Minnesota

Studies in the Philosophy of Science, IV, pp. 17-130. University of Minnesota Press, Minneapolis.

- Hatfield G. 1990. The Natural and the Normative: Theories of Spatial Perception from Kant to Helmholtz. MIT Press, Cambridge.
- Hempel C.G. 1954. A Logical Appraisal of Operationalism. *Scientific Monthly* 1 (No. 79), pp. 215-220.
- Hempel C.G. 1966. *Philosophy of Natural Science*. Prentice-Hall, Englewood Cliffs (N.J.).
- Holzkamp K. 1967. *Wissenschaft als Handlung. Versuch einer neuen Grundlegung der Wissenschaftslehre*. De Gruyter, Berlin.
- Houkes W. 2009. The Nature of Technological Knowledge. In: A. Meijers (ed.), Handbook of the Philosophy of Science. Volume 9: Philosophy of Technology and Engineering Sciences, pp. 309-350. Elsevier, Amsterdam.
- Hoyningen-Huene P. 1987. Context of discovery and context of justification. Studies in History and Philosophy of Science Part A, 18(4), pp. 501-515.
- Janich P. 1992. Grenzen der Naturwissenschaften. Beck, München.
- Jonas H. 1979. Toward a Philosophy of Technology. Hastings Center Report. 9: 2–54.
- Knorr Cetina K.D. 1992. The Couch, the Cathedral, and the Laboratory: On the Relationship between Experiment and Laboratory in Science. In: Pickering (ed.) 1992, 113-138.
- Kuhn Th. S. 1962[1970]. The Structure of Scientific Revolutions, University of Chicago Press, Chicago (quotations are from the second edition, 1970).
- Lenk H. 1982. Zur Sozialphilosophie der Technik, Suhrkamp, Frankfurt a.M.
- Lorenzen P. 1987. *Lehrbuch der Konstruktiven Wissenschaftstheorie*. Bibliographisches Institut, Mannheim.
- Mittelstraß J. 1974. *Die Möglichkeit der Wissenschaft*. Suhrkamp, Frankfurt a.M.
- Niiniluoto I. 2016. Science vs. Technology: Difference or Identity? In: M. Franssen et al. (eds.), Philosophy of Technology after the Empirical Turn, 93-106. Springer, Basel.

- Nordmann A. 2006. Collapse of distance: Epistemic strategies of science and technoscience. Danish Yearbook of Philosophy, 41, pp. 7-34.
- Pickering A. (ed.) 1992. Science as Practice and Culture, University of Chicago Press, Chicago.
- Pinch T. and W. Bijker 1984. The Social Construction of Facts and Artefacts: Or How the Sociology of Science and the Sociology of Technology Might Benefit Each Other. Social Studies of Science 14, pp. 399-441.
- Rapp F. 1978. Analytische Technikphilosophie, Alber, München.
- Redtenbacher F. 1848. Resultate für den Maschinenbau, Bassermann, Mannheim.
- Rumpf H. 1973. Gedanken zur Wissenschaftstheorie der Technikwissenschaften. In: H. Lenk und S. Moser (hrsg.), Techne, Technik, Technologie. Philosophische Perspektiven, pp. 82-107. Saur, Pullach, 1973.
- Schickore J. and Steinle F. (eds.) 2006. Revisiting discovery and justification: historical and philosophical perspectives on the context distinction. Springer, Dordrecht.