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Atti del 9° Convegno Nazionale

Naples, 2022 May 16th - 17th

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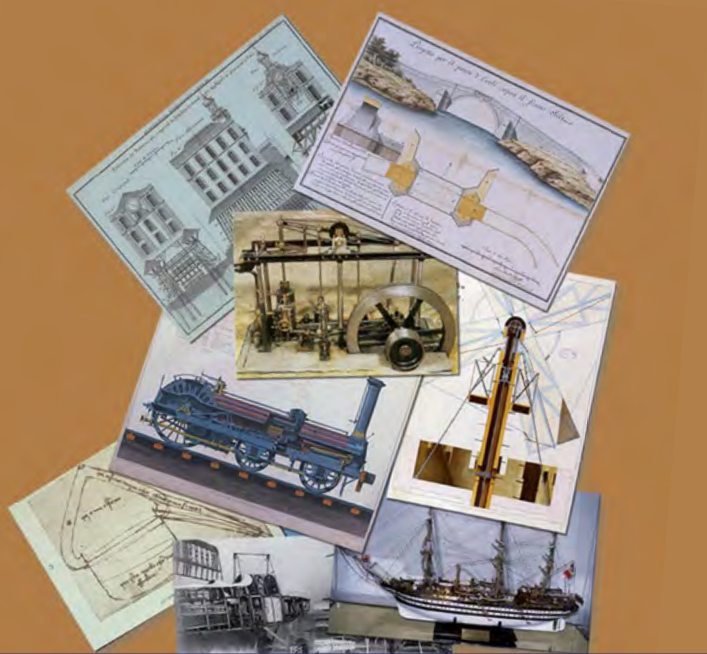

Cuzzolin

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Storia dell'Ingegneria

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Science and technology. The physicist and the engineer

Scienza e tecnologia. Fisici e ingegneri

Abstract
The terms science and technology are commonly meant to designate different yet cognate activities. Their divide, however, can hardly be expressed. When dealing with the question whether a certain problem pertains to science rather than technology (or the other way round), people tend to identify the two realms more or less in the same ways or to respond with an admission of ignorance. If, instead, people are asked about the difference between science and technology in general, they tend to give more dispersed and uncertain answers. According to a widespread narrative, science has more to do with theorization, abstraction, generalization, simplification through modelling, whereas technology is committed to the actual reality, measurements in concrete scenarios, individual cases, entangled conditions. In our paper, we briefly illustrate the epistemological as well as sociological motivations of the common answer sketched above and suggest to pose the question of the distinction and the positive relation between science and technology assuming a historically-informed point of view. Historians of modern technology have identified the birth of a new actor in the European cultural milieu of the 18th century: the scientific engineer. The goal of this new intellectual figure, often well trained in mathematics, was the rationalization of design and implementation of processes. For this purpose, hypotheses and experimentations were employed, as in the (mathematical) physical sciences; on the other hand, data from technical ateliers, shipyards, etc., were requested and utilized. The need for such a new figure derived from the tumultuous developments of science of the 18th century, consequence and cause of the economic development, requiring a growing body of qualified engineers. On this background, the engineer – the actor who is entrusted with technological knowledge – appears as a sort of middle term in a twofold relation: the intermediate operator between the scientist and the final user.

Sommario
I termini scienza e tecnologia sono comunemente intesi per designare attività diverse ma affini. La loro distinzione, tuttavia, può difficilmente essere espressa in modo semplice. Quando si tratta di decidere se un certo problema riguardi la scienza piutto-

sto che la tecnologia (o viceversa), le persone tendono a identificare i due ambiti più o meno allo stesso modo o a rispondere con un'ammissione di ignoranza. Se, invece, le si interroga sulla differenza tra scienza e tecnologia in generale, le persone tendono a dare risposte più disperse e incerte. Secondo una narrativa diffusa, la scienza ha più a che fare con la teorizzazione, l'astrazione, la generalizzazione, la semplificazione attraverso la modellazione, mentre la tecnologia è impegnata nel mondo reale, nelle misurazioni in scenari concreti, in casi individuali, in condizioni intrigate. Nel nostro lavoro illustriamo brevemente le motivazioni epistemologiche e sociologiche della risposta comune e suggeriamo di porre la questione della distinzione e del rapporto tra scienza e tecnologia assumendo un punto di vista storico.Gli storici della tecnologia moderna hanno individuato la nascita di un nuovo attore nell'ambito culturale europeo del XVIII secolo: l'ingegnere scientifico. L'obiettivo di questa nuova figura intellettuale, spesso ben preparata in matematica, era la razionalizzazione della progettazione e dell'attuazione dei processi. A questo scopo si impiegavano ipotesi e sperimentazioni, come nelle scienze fisiche (matematiche); erano anche richieste e utilizzate informazioni provenienti da atelier tecnici, cantieri navali, ecc. La necessità di questa nuova figura derivava dai tumultuosi sviluppi della scienza del XVIII secolo, conseguenza e causa dello sviluppo economico, che richiedevano un corpo crescente di ingegneri qualificati. Su questo sfondo, l'ingegnere – l'attore a cui è affidata la conoscenza tecnologica – appariva come una sorta di termine medio in una duplice relazione: l'operatore intermedio tra lo scienziato e l'utente finale.

Introduction

On 10 April 2019 the Event Horizon Telescope Collaboration – a Very Long Baseline Interferometry-VLBI project with several connecting stations operating worldwide – released the first image of the shadow cast by the event horizon of a black hole, i.e. «the closest we can come to an image of the black hole itself»[1] This success was due to many complex and intertwined factors. They include, for example, the calculation of the photon orbit forming a bright ring around an event horizon and the expectation that «when surrounded by a transparent emission region, black holes ... reveal a dark shadow caused by gravitational light bending and photon capture at the event horizon» (EHT Collaboration et al., 2019a: 1); the observation and growing understanding of the active galactic nuclei and the general acceptance that they are powered by «supermassive black holes accreting matter at very high rates through a geometrically thin, optically thick accretion disk » (ibid.); observational evidence regarding supermassive black holes with the largest apparent event horizons.

Advances in the instrumentation were crucial as well to attain the desired goal. The Event Horizon *Telescope* can be described as «a global ad hoc VLBI array operating at 1.3 mm wavelength» (EHT Collaboration et al., 2019b: 1). It resulted from the insight that worldwide VLBI was possible, which emerged since the 1970s, after a decade or so of observations in more limited VLBI arrays (Kellermann and Moran, 2001: 476-481), as well as from the application of the VLBI technique to very short wavelengths and the treatment of noise under such conditions. However, the EHT had also to face new challenges in data processing, calibration, and imaging that required the development of specialized techniques, and substantial improvements are expected from the "next-generation Event Horizon Telescope" program (ngEHT), launched in September 2019[2].

Was this enterprise "science"? Or was it a technological exercise? It was obviously both. But where is the divide? To what extent was it science, and where does science end, and technology begin? In fact, episodes like this, whether or not they end up with success, challenge our attempts to demarcate science from technology – beginning with the fact that "hyperteams" that characterize enterprises like the EHT Collaboration (and many projects in high-energy, particle physics, and astrophysics) are interdisciplinary groups where the engineer and the physicist frequently work side by side in order to solve common problems.

After all, and in very general terms, current usages of the term technology explicitly or implicitly involve the reference to a quadrille of concepts – design, production, maintenance, and use – and their relations to human artifacts. To put it as Mitcham (1994; 2009) and Radder (2009), technology may denote (i) a set of artifacts (or systems of artifacts) that are designed, produced, maintained, and used in certain activities; (ii) a form of knowledge regarding the design, production, maintenance, and use of technological artifacts and systems; (iii) a range of activities concerning the design, production, maintenance, and use of artifacts; (iv) an expression of the will or an act of volition by those who have designed, produced, maintain operating and use certain artifacts.

In this perspective, since the Event Horizon Telescope is an artifact which had to be designed, produced, maintained operating, and employed, it involves technology in one or more of the above-mentioned meanings. But it also involves science both in its final purpose (the knowledge of the cosmos) and in the precise knowledge of the abstract principles governing its feasibility and functioning (geometric optics, electromagnetism and theory of waves, general relativity, etc.).

Finally, as regards our four meanings of technology, none of them is correct or incorrect in itself. Rather, they reflect four ways in which technology is accounted for. In the present paper, we mostly refer to the second meaning, but to be sure a set of artifacts can be considered as a piece of technology, and this involves the activities in which artifacts are designed, produced, maintained and used, as well as the intentionality both of the makers and the users.

However, the second meaning of technology has two important advantages that we shall point to in the following sections. First, it highlights a direct relation of technology to a form of knowledge, thus allowing to get rid of an outdated image of technology as "applied science". Second, it puts in the foreground the intellectual figure of the engineer as the holder (and the carrier) of that particular form of knowledge.

In the final section, we shall claim that the combination of these two features suggests the establishment of an epistemology of technology in its own right, based on Hacking's (2009) notion of "style of thinking". According to the view we develop, although technology does enter in relation with science in multiple ways, it is nevertheless endowed with relative independence from the scientific discourse.

Technology as applied science and its discontents

According to an outdated but influential definition, technology is not but an application of our (best) scientific theories. This point of view has been stressed and explored in detail by Mario Bunge (1966) within the complex of his theory of science (Staudenmaier, 1989: 96-99; Houkes, 2009). Let us take the following assertion: «The method and the theories of science can be applied either to increasing our knowledge of the external and the internal reality or to enhancing our welfare and power. If the goal is purely cognitive, pure science is obtained; if primarily practical, applied science. Thus, whereas cytology is a branch of pure science, cancer research is one of applied research» (Bunge, 1966: 329).

As noted by Radder (2009: 69-70), Bunge is claiming that the divide between science and technology can be expressed in terms of their aims. Cancer research may produce new particular knowledge about cancer, but since it is aimed at finding therapies against this group of serious diseases, thus relieving pains of certain living beings, it is applied science. In doing this, cancer research crucially utilizes the accomplishments of cytology, which studies cell structures in themselves, without considering the welfare of a certain person suffering from, say, an abnormal cellular growth in this or that tissue. Hence, cancer research is a kind of technology: it applies our best scientific knowledge from cytology to enhance welfare.

However, Bunge's approach is doubtful both on historical and theoretical account. As is well known, Ernst Mach's "historical-critical" reconstruction of the history of mechanics offers an idea that is diametrically opposed to Bunge's: «The branch of physics which is both the oldest and the simplest, and which is therefore treated as introductory to other departments of this science, is concerned with motions and equilibrium of masses. It bears the name of mechanics. It also affords a simple and instructive example of the processes by which natural science is generally developed … An instinctive, irreflective knowledge of the processes of nature will doubtless always precede the scientific conscious cognition – i.e., the investigation – of phenomena. The former is attained by putting into relation the natural processes with the satisfaction of our needs» (Mach, 1883: 1).

One could object that Mach's statement is as one-sided and a-prioristic as that of Bunge. However, it is hardly questionable that historically, practically directed knowledge ("technology" or "applied science" in Bunge's sense) at least "often" precedes epistemically directed knowledge ("pure science"). On the other hand, if taken at its face value, Bunge's conception brings to the paradoxical conclusion that technology as applied science would emerge when there is no science at all that can be applied.

Bunge's aim-centered demarcation between technology and science is also theoretically unsatisfying, since it is not clear how the aims of a research are to be determined. On the one hand, if they are determined through the actors' intentions, then the actors may disagree about their goals when involved in the same investigation or discipline. Suppose that, of two specialists on cancer research, one is interested into saving his patients' lives whereas the other is just interested into a better knowledge of the mechanisms of abnormal cellular growth. Suppose that we have good reasons to consider both doctors honest about their aims. In light of Bunge's definition, we are forced to think that only the former is doing applied research, whereas the latter does pure science, since her or his goal is authentically epistemic.

On the other hand, if the goals are thought as a somewhat intrinsic property of a research – as the orientation toward an end, that is what philosophers often label the "intentionality" of a course of action – other problems emerge. Let us come back to the image production in the EHT Collaboration. It is reasonable to assume that the image was the intrinsic aim of the project, since the VLBI network constituting the telescope was designed in order to get it. Now, what kind of a goal is the image, framing it in Bunge's conception? It certainly confirms our theories regarding how black holes and their surrounding space are structured but increases the stand of our knowledge about the processes powering most galaxies, and thus it certainly increases "our knowledge of the external … reality". So, one is tempted to list it under the column "pure science".

However, what is 'pure' in Bunge's terms here is not the "image-as-a-goal", but the "goal-of-the-image". Let us leave aside terrestrial aims such as prestige, enhancement of specific techniques, improvement of instrumentations, etc., which play an inescapable role in science, and consider the epistemic side of the question only. It is conceivable that scientists wanted to get the image in order to improve our knowledge about the cosmos. But this is not the aim of that investigation; this is the aim of astrophysics and cosmology as a whole. Astrophysics and cosmology are oriented to getting images because they are interested in the growth of knowledge about the cosmos. That is to say, this is the intrinsic goal of the images; they are oriented toward an epistemic end: the improvement of knowledge. However, the intrinsic goal of the EHT is a little bit different: it is getting the image, regardless of the goal of the image. To this end – i.e., for getting the image – the EHT instrumentally utilizes 'pure knowledge' coming from many different disciplines such as particle physics and astrophysics, geometrical optics, mathematical theory of errors, etc., along with other technological advances. So, we are forced to the implausible conclusion that in itself the EHT is not pure science but a technological application of n^{th}-order; however, as part of astrophysics and cosmology, it shares their cognitive and thus scientific aims.

Bunge's view exemplifies the kind of paradoxes one has to face starting with formal definitions of science and technology in terms of the identification of a set of characteristics, requirements, and criteria that a certain practice should satisfy in order to be described as one or the other; for other criticisms of such an *a priori* or "essentialist" strategy, see (Radder, 2009). A way to circumvent aporias of this kind is the so-called "finalization theory" of technology (Böhme et al., 1976; Krohn and Schäfer, 1983: 17-52). A conception that mainly emerged in Germany during the 1970s, it bears some similarities with Kuhn's (1962) image of the scientific development as an alternating interplay of a "normal" or "paradigmatic" phase and a "revolutionary" phase. According to the proponents of this view, scientific disciplines begin to form – as in Kuhn's image – in a pre-paradigmatic phase, characterized by a plurality of worldviews and methods.

The second step is the construction of a paradigm in Kuhnian terms, aimed at "the empirical and conceptual articulation and validation of the central theoretical ideas" (Radder, 2009: 75). In this second phase scientists tend to build up "closed theories". These are theories that (i) are sufficiently broad to capture the essential features of a certain fields; (ii) their validity has been tested over a number of instances, so they have enough empirical evidence to attract a vast audience and find supporters; (iii) is reasonable to think that they can be extended to novel phenomena in the same realm (and maybe beyond). Under such conditions, the belief is widespread that the fundamental work for a certain scientific picture has been accomplished and only the details should now be worked out.

In these two phases, researchers are mostly faced with the "internal" problems of the individual theories they are dealing with – their primary goal is the development of a picture as complete as possible, whereas practical applications remain in the background. Only in a third, "post-paradigmatic stage" scientists «become oriented towards external goals and interests through the development of "special theories" (sometimes also called "theoretical models") for the purpose of realizing certain technological applications. It is at this stage that science becomes finalized.» (Radder, 2009: 75).

Even if the finalization theory clarifies in what sense and through which processes scientific cognitions can emerge as "applied sciences", it is still doubtful whether this picture can be generally applicable even in the field of the physical disciplines, that their advocates take as a clear example of its validity. Many theoretical advances in high-energy and particle physics could not have been possible without the "finalization" of the existing atomic theories, well before they were satisfying (before the creation of the Standard Model, for example), in order to build nuclear reactors, not to say bombs, to study and theorize chain reactions and how to control them. Much of the present theoretical research in physics could never have been possible without fundings for military applications (Forman, 1987). The creation of scientific networks, so instrumental in today scientific disciplines, could never have been developed, if it would not been driven by international diplomacy in view of possible applications – no matter if established theories or robust knowledge already existed or not (Rentetzi and Ito, 2021).

The birth of a new figure

A border line is not just a dividing line that makes clear the difference between two distinct areas – it's also a common border between regions, which may allow transitions, transfers, even trafficking within a divided and still common ground (Tagliagambe, 1997). Of course, in a certain sense, rules that allow or forbid passages from a region to another are given *a priori*, are partly shared by the regulators of the regions involved, and identify the borders, the agents and the wares whose exchange is allowed or not. However, rules may change as new wares or new agents appear on the market, and conditions are modified. In this sense, exchanges along any border form a dynamic system, whose mechanisms are better understood if not only possible abstract rules are taken into consideration, but also, e.g., exchanges wares and rates as well as the actors involved in the exchange.

Applying this metaphor to our case, we suggest that an understanding of the science/technology divide is better developed if one considers the actors involved on the two sides of the border, what they can exchange and how exchanges are accomplished, when they are performed, etc. Of course, this seems to be a research project for the future much more than the designed content of a single paper – what we can do here, is just try to give an idea of the lines along which this project can be put forth.

Beginning with the era of exploration (XV-XVII century), important changes such as the widespread use of gunpowder in the warfare, the navigation of oceanic routes allowing the circum-navigability of the globe, the implementation of a more efficient state administration as a consequence of the rise of the national states (particularly in England, France, and the Iberic Peninsula), start shaping in new ways the relationship between societal and economic demands and advances in the knowledge of nature and artifacts. A route needs to be calculated as exactly as possible before a trip and must be kept up to date during the navigation. This required special techniques involving, e.g., the use and construction of more and more effective compasses, the representations of geographic maps, a special knowledge of astronomy and optics for the purpose of navigation, the crafting of ships, etc. (Singer, 1954). On the other hand, the spread of modern artillery based on the propellant effect of gunpowder required experts in ballistics (for attacking warfare) as well as in fortification (for organizing the defenses).

Meanwhile, movable type-printing ensured that knowledge could circulate simply and quickly and the supports promoting the diffusion of knowledge – namely, books – could be reproduced practically in any part of an expanding world.

The increasing complexity of military and civil enterprises urged the rulers to employ, at many different levels, qualified people with skills in mathematics. Thus, the best equipped actors who could contribute to the satisfaction of the novel needs of the early modern age were neither artisans just committed to the manufacture of particular artifacts nor philosophers of nature engaged in the understanding of the terrestrial or celestial cosmos.

The new order of things required somebody who was prepared to get his hands dirty but sufficiently skilled in mathematics to do it rightly. Somebody who could draw maps and map possible routes, who was able to calculate how to cause severe damages into the enemies' defenses and how to build countermeasures as robust as possible, who knew how to find a way to measure the growth of a nation (whatever it may mean) so that the population welfare can be further improved. Many complex conditions of this kind led to the emergence, during the 15th century and until the 1650s, of a new class of scholars, mostly technicians with a significant scientific, mostly mathematical background (Gille, 1964; Grafton, 2002; VanDyck and Vermeir, 2014). Their name was engineer in the anglo-saxon world, *ingénieur* in the French-speaking area, *Ingenieur* in the German-speaking countries, *ingeniero* or *engenheiro* in Spain or Portugal and their corresponding domains, *ingegnere* in the states of the Italian peninsula. This figure is nuanced as always happens when one wants to search in the past profiles, quite well defined today but not in the past. Whereas terms as scientists and physicists were coined by academicians, engineer originated in everyday usage. (The English term engineer traces back to the 14th century, with a somewhat unclear etymology; it would derive from the late Latin *ingenium*, or devices. Note that in the classical Latin *ingenium* means, talent and genius. This is a different possible origin for the Italian *ingegnere*. For example, Leonardo da Vinci referred to himself as an *ingegnero*. In the Middle Ages, c. 1292, the term was used to indicate devices or machines, from this the English engine. In the classical Latin device is translated as *machina*).

For some time, the term engineer and its equivalents in the European languages frequently appeared associated with specifications like artist-engineer, scientist-engineer, architect-engineer, administrator-scientist-engineer, *et similia*. The chief idea, however, remained that of a scholar who not only deals with the understanding of an artifact but is committed to its design. So, the design phase by means of drawing became more and more distinct from that of the construction of an artifact and the execution of the task this was designed for.

The form of contribution requested to the engineers changed or extended through time. Over the 16th and 17th century – a period that is little explored by the historians of engineering – "scientists" were summoned as consultants for supervising technicians working on particular facilities or buildings, e.g. canals, architectural works, fortifications, etc. Also, there was no clear divide between the natural scientist preoccupied with the theoretical comprehension of natural phenomena and the engineer dealing with the design and supervision of civil or military instrumentation and structures. Correspondence of leading scientists in the early modern age shows how often they were required to intervene as experts in the discussion of engineering problems.

Two particularly significant examples are worth mentioning. The Flemish Simon Stevin (1548-1620) was active in various fields of engineering in the Netherlands. He worked in the service of the prince Maurice of Orange-Nassau and was part of various commissions for the realization of engineering projects. Throughout his life Stevin took care of the construction of mills and other hydraulic works, obtaining numerous patents for the invention of mechanical devices. His attempts at theoretical analysis of complex engineering problems resulted in the compilation of short treatises dedicated to topics such as, for example, the prevention of wear in the design of gear wheels.

Galileo Galilei (1564-1642) is certainly one of the most important founders of the abstract, mathematics-based investigation of nature through *sensate esperienze* and *certe dimostrazioni* – two expressions that he employed to make clear his method in a famous letter to the Grand-duchesse of Tuscany, Cristina di Lorena (Galilei, 1890-1909: V, 309-348). But he also gave advice to the Arsenale of Venice, built lenses and military compasses, taught the art of fortifications, operated as a consultant for the water regulation of the river Bisenzio for the Grand Duke of Tuscany (Valleriani, 2010).

In the social and economic development that led to the industrial revolution on the one hand and the crisis of the *Ancien Régime* and the rise of bourgeoisie on the other hand, things changed rapidly. The understanding of the world increased as an effect of the extension of the Newtonian paradigm to new realms, causing a growth of novel and relatively independent fields; the economic and social demands to the raising number of engineers became more and more specific, causing a specialization of both the knowers and the knowledge. Throughout the 18^{th} century the demand for qualified technicians became so high in France that, to satisfy the increasing requests of military and civil projects, new schools were founded: e.g., the École *royale des ponts et chaussées* (1747), the *École royale du génie de Mézières* (1748) the *École des mines* (1783). In the same decades or so, similar institutions were established in England and Germany as well Belhoste, 1989; Belhoste, 2003) [1].

To limit ourselves to the formation period of engineering, a comprehensive account of these developments should further mention two other important facts: 1) The role of the bourgeoisie in the different national states (including the USA and the South America) in encouraging the institutions for the promotion of scientific culture and the various 'associations for the advancement of science' that flourished since the end of the 18^{th} century (Hall, 1961; Channell, 2009: 126); 2) the birth and rise of the *École Polytechnique* (1794) in France and, through it, the role of the French Revolution in promoting the alliance between the scientists and the engineers through the contributions of leading figures as Lazare Carnot and Gaspard Monge.

Conclusion: the relative independence of the scientist and the engineer

The few examples given above nonetheless suffice to show that in many cases the scientist and the engineer were embodied in the same person. A process of specialization has been ongoing for much time and lasted approximately one hundred fifty years – say, from the beginning of the 18th century until mid-19th century. Of course, periodization may vary depending on the different disciplines considered, but a complete separation of the two figures has been reached only recently. However, in most occasions the single scientist-engineer did *not act* at the same time both as a scientist *and* as an engineer. They are like different roles that an individual actor could possibly play in the same drama. The role that is required during the action – or, the kind of agency coming into question – is largely determined by the setup of the scene and the mutual relationships among the other roles.

Of course, there were and remain significant overlaps between the 'scientist' and the 'engineer', so the distinction remains a fuzzy one, which gets larger and clearer in complex projects requiring a somewhat sophisticated division of scientific labor (Auyang, 2004: 16; Boon, 2011). For the distinction to be meaningful, it should take into account both the interchange and co-dependence of competences as well as the epistemic differences (Hookes, 2009; Boon, 2011). A possibly useful tool to do this is Hacking's notion of "styles of thinking" or "styles of reasoning".

According to Hacking (2009: 6), these are «distinct ways to find things out», practiced in various cognitive activities that for historical reasons we consider "scientific" in a broad sense. Styles of thinking are grounded in cognitive capacities that have emerged in the course of human evolution, thus with reference to the needs and problems posed by a certain environment as well as in connection with other skills that had already been developed or whose development was ongoing in a certain time and space. On the one hand, each style «has been developed in its own way, in its own time frame», while on the other hand contributing «to the larger fabric of scientific imagination and action.»

Let us take an example. Following Hacking (2009), Galilei was able to discover a novel way for investigating nature – more precisely, a novel way of «what it is to tell the truth about nature» – through the mathematical modelling of natural facts and the experimental control of consequences resulting from an application of the hypothetical-deductive logic to the physical reality. The realization of this style of thinking was the effect of a certain mode of understanding mathematics and its relation to the world, the development of experimental methods, the acquaintance of Galilei with craftsmen and their workshops, etc.

Analogously, an engineering style of thinking may consist in a novel way of understanding the relation of the natural facts to human needs and intervening in the process. The primordial emergence of such a cognitive capacity – let us call it a technological cognitive capacity – traces back to the early stages of the human evolution, and for this reason we find a sense of technology long before most scientific disciplines have made their appearance. Since then, the technological capacity has grown richer and richer while the continuous change of conditions stimulated other cognitive skills as well. At a certain point of this story, styles of thinking connected with what in the course of time was being called "scientific disciplines" (particularly mathematics and physics) joined with the technological capacity. This relatively new connection was possible because the carriers of some mathematical knowledge was suited in order to respond the economic and social needs of the time. Gradually, more and more specialization was desired, or revealed as necessary, and a new figure summing up these two features – the capability of technological intervention into the world joined with scientific knowledge about the world – finally emerged. This was the engineer, the representative of a style of thinking which is deep-rooted in human cognitive skills, has a profound relationship with other (scientific) styles of thinking, but is essentially independent from them.

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[1] Khattab A. 2021. https://www.designingbuildings.co.uk/wiki/History_of_the_Institution_of_Civil_Engineers

Notes

1. See the EHT Press Release: https://eventhorizontelescope.org/press-release-april-10-2019-astronomers-capture-first-image-black-hole, last accessed November 2021.
2. More on the ngEHT at https://eventhorizontelescope.org/blog/nextgeneration-event-horizon-telescope-design-program.