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Considerations on the Nature of Science and Technology

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Abstract

In recent years, with the increasing development of science and technology, there has been a visible increase in studies aimed at better understanding the nature of science (NoS), both from an epistemological point of view, as well as a need to improve science teaching methods. In this way, many congresses and meetings aimed at exchanges in the field of the History of Sciences have been devoting more and more space to these issues. In them, the increase of works directed to NoS or NoSK (Nature of Scientific Knowledge) is notorious. In this paper, we intend to bring some fundamental elements to the discussion of this complex debate.

Keywords

Epistemology, Nature of Science, Nature of Technology, Scientific Development

1. Introduction

Throughout this text, we intend to present arguments that support the statement that scientific knowledge is an open, unfinished historical project, always moving towards objective and universal knowledge of the natural world, society, or the mind[1]. This project always aims to achieve increasingly precise and truthful knowledge, as it is based on reason. It is also notable that it contains the ines-

[1]This paper articulates the traditional concepts of science, technology, and philosophy in a dynamic and therefore historical perspective. We know that both science and technology are forms of knowledge developed by humanity over centuries. Evidently, both have specificities that we try to show throughout the paper. When we propose to advance in the understanding of the nature of science (NoS), we are not looking for a new definition for science and technology, but we are simply trying to add new, less visible dimensions and new aspects or new characteristics of knowledge in order to enrich it. Establishing a concept that is consensual should not be useful for its understanding. It is natural and promising that it continues to generate discussions and controversies. This is even a proposal from Popper when he postulates that instead of working to prove theories, it is much more fruitful to constantly try to refute them.

capable contradiction in which the project is involved, because it always aims for precision, knowing that it is procedural and even more so, if perfection or accuracy were achieved, it would be the end of the project itself. Thus, the denomination of any field of scientific knowledge as "exact sciences" is an epistemological inadequacy or even an aberration. Simply because science would be divided into two fields, that of the so-called human or social sciences, imperfect, inexact, and another endowed with the privilege of being exact, impeccable, and immutable knowledge. If this "epistemological cut" actually existed, we would have two types of sciences: one of inaccuracy, of "inexact sciences" and the other of perfection, of "exact sciences". Fortunately, this does not happen as we intend to show throughout this discussion.

Science, as we understand it, constitutes the set of knowledge constructed by schools, universities, and research institutions, forming with this sum a system of knowledge acquired by humanity throughout history, forming, so to speak, a large library-laboratory like said Michel Paty (Paty, 2017). As a natural consequence of the approximate nature of scientific knowledge, it is also not cumulative, as it is constantly constructed and rebuilt in the light of new developments, comprising a Trinitarian dynamic: construction, deconstruction, and reconstruction.

Another fundamental characteristic of scientific knowledge is that it is elaborated and constituted by symbolic forms without this removing any necessary requirement to represent the physical or social world. Symbolic forms are the fruits of thought and form thought objects, such as concepts, language, or formalizations, and signify the concrete thought in correspondence with the concrete of the natural or social world.

2. There Is No Exact Science

As scientific development is historical, every scientific theory has a provisional dimension and, in principle, can be altered or even completely replaced by another, whenever a new phenomenon that does not fit into the body of the theory calls the older one into question (Oliveira, 2020). This means that throughout history, human beings have also been building new instruments and forms of knowledge that could improve or replace theories that do not respond to the challenge posed by new phenomena. It only makes sense, therefore, to talk about the veracity of knowledge if we take this provisional dimension into account, knowing that they can be reformulated or even refuted. Another interesting consequence is Karl Popper's (1902-1994) proposal for the so-called demarcation between scientific knowledge and pseudoscientific knowledge. As knowledge is approximate, it means that it incorporates, and is inherent in, a certain amount of inaccuracy. The proposal to establish a demarcation, placing a border between knowledge considered scientific and non-scientific, loses a little meaning, because the side demarcated as scientific always contains a part made up of errors and approximations for a given historical moment. Over time, the territory of inaccuracy may or may not be debugged. Its provisional nature will decide whether the degree of approximation will increase, or whether it will be a problem for the theory considered and its dynamics move towards questioning it and even its rejection.

Considering what was said above that scientific knowledge also involves a portion of error, which gives this knowledge an approximate character, it is necessary to be very careful with statements that scientific knowledge is cumulative. The most we can say is that as a whole or in many fields, the volume of knowledge accumulated throughout history tends to increase, but its internal dynamics do not guarantee that its unknown portion will decrease over time, although this is the purpose of the scientific investigation. Exactly the opposite could happen, that is, that in that unknown part lies exactly the problem that could make that theory inconsistent with the new discoveries to the point that the entire scientific building would have to be demolished and a new theory would be built in its place compatible with the new reality.

Looking in the opposite direction, speaking of exact sciences would mean that scientific knowledge, at least in that field, has reached a definitive stage and can no longer be changed. The exact term means, precisely, that nothing could be removed or added from that content. If this were so, knowledge would deny itself and reach the status of dogma, that is, absolute truth, in no case questionable and placed on a pedestal of perfection and petrified. This would result in a detachment between reality, always in movement, and a static and immutable system of representation.

Fortunately, that doesn't happen. The knowledge process is dynamic, vulnerable to criticism and questioning, including the most radical, and can be replaced by another more appropriate, more powerful interpretation and explanation.

3. Mathematics and Logical Systems Develop Historically

The historical dimension of scientific knowledge is a general characteristic that permeates all fields of science. If mathematics and logical systems can claim greater rigor and precision, they nevertheless contain a provisional dimension that is reflected in the multiple questions to which they were constantly subjected throughout their development. If we take Newton (1642-1727) and Leibniz's (1646-1716) infinitesimal calculus as an example, we can observe that since its beginning multiple attacks of inconsistencies have been raised. Johann Bernoulli (1667-1748) and George Berkeley (1685-1753) were among the first to raise questions. The alleged inconsistencies were addressed both to its operational capacity, that is, its algorithmic form, and to the context of justification of its scientificity. Thus, we can cite Berkeley's work, *The Analyst*, published in 1734 (Berkeley, 2002). Also, in the correspondence that Leibniz maintained with Johann Bernoulli, the discussion largely focused on the existence of infinitesimals. In 1742 Maclaurin (1698-1746) published a *Treatise on Fluxions* (Maclaurin, 1801), dealing exactly with the foundations of calculus in his Newtonian approach, that is, in the method of fluxions (Newton, 1994).

At the time of Newton and Leibniz, the great mathematicians from both England and France participated in these discussions, such as Varignon (1654-1722), Malebranche (1638-1715) and the Marquis de L'Hôpital (1661-1704), responsible for the first calculus book published in 1699 (l'Hôpital, 1699). The debates and questions continued until the 19th century. It was only with Augustin-Louis Cauchy (1789-1857) who introduced greater rigor into the foundations of calculus that the conceptual basis of calculus reached the level it still has today. Cauchy's works were published between 1821 and 1829: *Course of Analysis* (1821), *Summary of Lessons on Infinitesimal Calculus* (1823) and *Lessons on Differential Calculus* (1829)[2]. It was no coincidence that this systematization developed by Cauchy was carried out at that time. It is concomitant with a great scientific development in France, where we can highlight the work of Sadi Carnot's (Carnot, 1824) heat theory and Fourier's (Fourier, 1822) mathematical theory of heat, in addition to a broad progress in French engineering and many of the disciplines that are taught today in engineering schools such as applied mechanics, strength of materials, fluid mechanics and others.

In the summer of 1900, Bertrand Russel (1872-1970) participated in the first World Congress of Philosophy, held in the city of Paris[3]. On this occasion he met the Italian mathematician Giuseppe Peano (1858-1932) and learned about his studies in logic. In the autumn of the same year, Russel studied his conceptions and completed the work on a logic of relationships. In 1905, Russell developed his theory of descriptions and in 1910 published the first volume of his work in partnership with Whitehead (1861-1947), *Principia Mathematica*. The complete work would be published in three volumes, in 1910, 1912 and 1913. With it, an intellectual movement known as analytical philosophy began (Russel & Whitehead, 1910).

The fundamental idea of analytical philosophy, at least at its beginning, was to consider that philosophical difficulties arise because we fail to understand the more general notions on which these difficulties are based, and thus, to resolve them it is necessary to carry out a conceptual analysis of the notions, problematic and in this analysis, make the logical forms on which they are based emerge. Then mathematics would provide the model. Bertrand Russell thought he had discovered a new mathematical technique that would put philosophy on the path to science. The result was very different from what was expected.

[2]Before Cauchy's works, especially his *Cours d'Analyse*, the community of mathematicians was divided on the validity of infinitesimal calculus. Within the French Academy of Sciences, opposition to calculus was led by Michel Rolle and in England the biggest opponent was George Berkeley. The main question revolved around how to treat infinitesimal quantities. Cauchy's work was fundamental in bringing greater rigor to conceptualizations and demonstrations, mainly with the introduction of the concepts of limit and continuity.

[3]At the International Mathematics Congress in Paris, in 1900, David Hilbert presented a surprising work summarizing the 23 questions still "open", which, after being resolved, would complete the entire scope of mathematics. Hilbert intended to trigger a general effort by the scientific community to complete the logical foundation of mathematics. What was seen was a general reversal of these expectations with Gödel's work.

But the greatest impact on logical systems came with the Austrian logician Kurt Gödel (1906-1978), who in 1931 proved the theorem that made him famous, in which any axiomatic theory that encompasses number theory cannot be completely axiomatized and that its consistency requires knowledge from outside the system (Nagel & Newman, 1958). The theorem refutes hopes for completeness and consistency within the same system[4].

4. Critique of the Hypothetical Deductive Model of Science

The hypothetical-deductive model (HDM) applied to current science has been subject to several questions, in order to incorporate certain characteristics of scientific development in recent years, mainly the possibility of processing large amounts of data provided by computer science driven by increasingly powerful equipment (Skiena, 2017). We will return to these new possibilities later.

The hypothetical-deductive model enshrines, so to speak, a certain vision and model of science that has been established since the precursors of the Scientific Revolution itself, which reached its crowning achievement in the 17th century. In this way, Francis Bacon (1561-1626) introduces induction as a method of empirical sciences, although its oldest roots lie in the thought of Aristotle (384 aC-322 aC). Bacon, however, rejected the Aristotelian system of syllogisms. As we know, Hume (1711-1776) questioned the inductive method when analyzing the problem of causality (Hume, 1748).

The science model represented by the HDM then emerges, in the context of logical-positivism ideas, with the proposal to connect theoretical propositions and inferences with empirical observations. The HDM structure has the following configuration:

1) Scientists are faced with a collection of data for which they seek an explanation.

2) Some hypotheses are tested based on existing theories.

3) Experiments are designed to test these hypotheses, seeking confirmation or through Popper's falsifiability criteria (Popper, 1962).

4) Confirmed hypotheses are maintained and can be expanded and retested; those that do not pass the tests are rejected.

This model has been applied very successfully in high energy physics and other fields containing quantitative theories.

Recent advances, mainly in the last 30 years in computer science, data storage and retrieval, long-distance data transmission technologies and what is conventionally called high-performance computing associated with sophisticated sens-

[4]Kurt Gödel, in 1931, proved two theorems of mathematical logic, which established limitations inherent to almost all axiomatic systems. The first incompleteness theorem states that no consistent system of axioms, whose theorems can be listed by an "effective procedure" (for example a computer program that can be any type of algorithm), is capable of proving all truths about relations of natural numbers. For any of these systems, there will always be statements about the natural numbers that are true but that cannot be proven within the system. The second incompleteness theorem is an extension of the first and shows that such a system cannot demonstrate its own consistency.

ing processes, have produced new forms of inference and a new scientific standard was being formed. This new model is conventionally called the observational-inductive model (OIM).

The methodological structures represented by the two models presented, the HDM and the OIM, in fact, can act in a complementary way and apply to different scientific fields. The OIM can be very useful for resolving scientific controversies in fields such as cosmology where the experimental data base is limited and a certain degree of confidence in theory predominates.

5. Science Is Built by the Subject

Two characteristics are fundamental to the construction of scientific knowledge. The first is that he mobilizes a set of symbolic forms with which he operates and obtains novelty. These are concepts, languages, and representations that, as we have already seen, always have a historical dimension and are constantly changing. The second is that knowledge is created by the subject, being the center of all intelligibility. This knowledge, whether of the natural or social world, occurs with a strong commitment to objectivity, that is, it is adequate and adherent to the objective forms that it aims to represent. The social and historical dimension of knowledge is realized through intersubjectivity, that is, in contact with other individuals and this is how knowledge impacts society and transforms it. However, intersubjectivity is a very weak form of validating knowledge and its adaptation to reality occurs through other forms and mechanisms described in the previous item.

In the question of how newness arises, we can remember what Michel Paty stated: *New knowledge is possible and made effective by intermediating the function of rationality thanks to the expansion of the forms and categories of the rational* (Paty, 2010).

According to this point of view, it is its expansion that allows new relationships between concepts and even new concepts to be created, and thus ensuring new elements to knowledge. The emergence of novelty also raises the idea of invention or discovery and occurs in a similar way to what occurs in other fields of human activity, such as arts and technology.

As an example of the broadening of concepts creating the conditions for the emergence of novelty, we can exemplify how the theory of motion (Galilei, 1952) occurs in Galileo (1564-1642) and the so-called "broadening", first with Huygens (Huygens, 1673) and then with Newton using Kepler's laws until reaching theory of universal gravitation (Newton, 1952).

As we know, Galileo studied the law of free fall of bodies with his experiments on the inclined plane. In it, the vertical displacement during the fall is related to the descent time through a function of time squared. Huygens (1629-1695) then studies the circular movement of a body by rotating it around a fixed center, as is the case of a rope with a weight tied to its end and making this weight rotate with the hand as a fixed point. With this, Huygens proposes that the centripetal force, directed to the center, is equal to mv^2/r, with m being the mass, v its tangential speed and r the radius of the circle, which means the length of the rope going from the weight to the hand, considered the center of the movement. With these results obtained by Huygens, Newton, when applying it to the orbital movement of the planets and considering Kepler's (1571-1630) third law, concludes that the force of attraction between the sun and any planet rotating around it has the algebraic form of $1/r^2$ (Nauenberg, 2005).

We can observe that the concept of force was not yet present in Galileo's studies, with the wise Pisan having developed a kinematics for the free fall movement of bodies and for the movement of projectiles. Then the theory of movement is extended to the case of circular movement by introducing the concept of centripetal force. A new conceptual expansion is made by Newton, extending the concept of force, from circular motion, to the orbital motion of the planets and unifying the motion that happens on Earth, to free fall and circular motion to the motion of the planets and consequently proposing a theory for the gravitation of the solar system, including a mathematical model for the force of attraction that the sun exerts on all the planets.

6. Science Learns from Its Mistakes

One of the most emblematic cases of how science can learn from its own mistakes is the emergence and development of non-Euclidean geometries, based on a proposition that remained unproven in Euclidean geometry (Lobachevsky, 1840). This is the fifth postulate, known as the parallel postulate. Despite its firm establishment since Euclid (325 aC-265 aC), it failed to be demonstrated from the four previous postulates. For two thousand years, many attempts were made in this direction, and they all led to failure.

It was then that Russian mathematician Nikolai Lobachevsky (1792-1856) looked at the problem differently, leading him to discover and advance geometry, placing Euclidean geometry as a particular case of other geometries.

Lobachevsky graduated from Kazan University in 1811, earning a master's degree in physics and mathematics. With the growth of political tensions between the West and Russia, especially after the Napoleonic invasion of 1812, the Russian state began to reject the European university system. Later, in 1815, the Russian government banned Russian students and academics in general from studying at German universities. As a result, many foreign teachers left Russia.

It was in this context that Lobachevsky took up the position of assistant professor at Kazan University in 1822. Furthermore, Emperor Alexander I (1818-1881) did not believe in modern science, creating an environment of difficulties within universities. To make things even more complicated, Kazan went through a cholera epidemic in 1830 and in 1842 it suffered a massive fire that destroyed half of the city.

During a large part of his academic life in Kazan, Lobachevsky worked on what would become his greatest contribution to science, that is, the construction of a new geometry, called non-Euclidean geometry. At the same time, two other great names in mathematics felt challenged by Euclid's fifth postulate, rather than simply trying to demonstrate it. They were Carl Gauss (1777-1855), in Germany and Janos Bolyai (1802-1860), in Hungary.

The difference between Euclidean geometry and the geometry created by Lobachevsky lies in its postulates. Lobachevsky kept all four previous postulates unchanged, but modified the fifth as follows:

There are two lines parallel to a given line through a point outside it.

However, it defines a parallel line as:

A line whose extension in both directions does not intersect the line that is parallel to it.

As a consequence of his reformulation of the fifth postulate, the new geometry starts to have different properties from Euclidean geometry. The following five theorems were then stated:

Theorem 1: *The sum of the interior angles of a triangle is less than* π.

Theorem 2: *The sum of the interior angles of a quadrilateral is less than* 2π.

Theorem 3: *There are no rectangles.*

Theorem 4: *If two triangles are similar, they are congruent.*

Theorem 5: (*Universal Hyperbolic Theorem*). *Given a line l and a point P outside it, there are infinitely many lines parallel to l, passing through P.*

As already mentioned, both Janos Bolyai and Carl Gauss also reach results similar to those of Lobachevsky, however using other paths. Bolyai's work was titled *Supplement Containing the Absolutely Time Science of Space, Independent of the Truth of Falsity of Euclid's Axiom XI*, published in 1832. Euclid's fifth postulate was also known as Axiom XI.

Bolyai's work received very little attention from Western mathematicians. Furthermore, Gauss also began to claim recognition for his discovery of non-Euclidean geometry, claiming that it preceded Bolyai's. It is also important to add that Lobachevsky's insistence on publishing and defending his works, in fact, led to a recognition of non-Euclidean geometry.

In 1829, maintaining an involuntary isolation from his colleagues, Lobachevsky submitted his first paper on the new geometry: *A Concise Outline for the Foundations of Geometry*. The work was rejected and did not pass academic censorship. In Russia, his work was not understood and disregarded, which hit his reputation hard.

In 1832, Lobachevsky asked the University to send his work, *On the Principles of Geometry*, to be analyzed by the Saint Petersburg Academy. Academic Mikhail Ostrogradskii (1801-1862) was assigned to review it. His review said:

As it turns out that two definite integrals in Lobachevsky's work require to be calculated using his new method, one is already known and the other is false.

Furthermore, Ostrogradaskii noted that the work was done with very little care and that most of it is incomprehensible. So, he says: *In my opinion Lobachevsky's article does not deserve the attention of the Academy.*

In order to defend his points of view and his ideas about a new geometry, Lobachevsky published some more works. This way they emerged: *New Principles of Geometry with a Complete Theory of Parallels*, published by the University of Kazan in 1835 and in the same year, *Imaginary Geometry*, published by the University of Moscow. Another paper: *Geometrical Investigations on the Theory of Parallels*, translated into German and published in Berlin in 1840, had a great impact on scientific circles in Western Europe. Gauss wrote to the mathematician Heinrich Schumacher (1780-1850), praising Lobachevsky's work, and once again claiming to have arrived at the same results through other paths.

Gauss's recommendation led to Lobachevsky's appointment to the Göttinger Scientific Society, and he was elected a member in 1842. Unfortunately, this was the only recognition in his lifetime that Lobachevsky received for his work and for his acceptance of the existence of a new geometry. Only after his death would he be recognized by the St. Petersburg Academy. Lobachevsky died on February 24, 1856, in Kazan[5].

Examples of how science learns and benefit from its own mistakes are very numerous. Still in the field of the History of Mathematics, specifically in the history of dynamic systems, we have the famous example that occurred with Poincaré[6].

7. The Role of Ideology in the Sciences

If we observe the role that ideologies play in the sciences, we will see that they have a different character when it comes to natural sciences or social sciences. Furthermore, we can see that they suffered different historical and political conditions. This becomes clear when we examine the natural-scientific model of objectivity throughout history. Historically, it has always been marked by ideological assumptions and value judgments. For the natural sciences to acquire a certain freedom from value judgments, a long historical process was necessary. During feudalism, the weakness of the dominant classes in political-military relations gave decisive weight to ideological factors so that they could maintain the established order. The ideological framework at the time comprised a complex

[5]The discovery of non-Euclidean geometry had a huge impact on modern science. It was through it that mathematicians at the time arrived at new theories, such as the special theory of relativity, developed by Albert Einstein in 1905, in the work that became famous: *On the Electrodynamics of Bodies in Motion*. Furthermore, non-Euclidean geometry facilitated the understanding of the general theory of relativity. When Einstein was making progress with this theory, it was non-Euclidean geometry that provided the elements for the elegant formulation of the theory of space-time.

[6]Poincaré's error is a well-known example of how certain errors can boost knowledge. In 1885, Henri Poincaré submitted a work to be published in Volume 7 of *Acta Mathematica Journal*, published by Institute Mittag-Leffler a research Institute belonging the *Royal Swedish Academy of Sciences*. The title of the article was: *On the* 3-*body problem and the equations of dynamics*. Poincaré's work beat all competitors. However, in 1889 he sent a telegram to the Acta's editors asking them to stop printing due to an error he had detected. In 1890 Poincaré submitted a new version of the work, adding some important new features for the theory of dynamic systems. In addition, the paper later became one of the fundamental works of chaos theory. This is an example of how a mistake made in some scientific development can be fruitful for the advancement of scientific knowledge.

of dogmas and explanations coherent with the fixed and immutable order of the universe. This way it is easy to understand why any questioning of this system was a subversive threat and consequently treated with violence and repressive rigor. The first manifestations of questioning through the natural sciences were repressed with the same violence with which religious heresies were treated. It is within this framework that we must understand the trials and convictions of Giordano Bruno (1548-1600) and Galileo. A political-ideological confrontation took place in the field of knowledge of natural sciences and meant the transition from the Ptolemaic model of the universe to the Copernican model. The dissent and questions raised by Bruno and Galileo threatened the entire ideological edifice of the nobility and clergy during this period. Although both Bruno and Galileo were defeated, the Scientific Revolution of the 17th century advanced with great strides towards an acceptance that was close at hand.

With the advent and development of the capitalist mode of production, natural sciences tend towards a type of de-ideologization. This happens exactly because capital in general and large industry need scientific knowledge and in this way the conflict and ideological dispute move to the economic-social and, therefore, political terrain where the appropriation of knowledge will take place by the product generated by work. As soon as capitalism was established in the main cities of Europe, at the end of the 18th century and beginning of the 19th century, natural sciences could emancipate themselves and get rid of previous religious-based ideologies. It is precisely in this period that Enlightenment philosophers could enter the scene and direct their attacks against clerical obscurantism, religious feudalism, the principle of authority, scholastic dogmatism, this being a fundamental step towards the formation of a natural-scientific model of objectivity. These thinkers prepared the ground for eighteenth-century scientific knowledge to flourish (Oliveira, 2013).

Later, as this model of scientificity matured, an epistemological ideal began to form based on a science free of ideologies, value judgments and political assumptions, a kind of neutral science. This ideal taken to its ultimate consequences resulted in the positivist model of science.

The ideological question persists, obviously, in the natural sciences, but in another form. The selection of its object for research, the technical applications of its discoveries depend to a large extent on class interests or social groups that finance, control, and guide its development. Not to mention the ideology of researchers and men of science.

Even in the current model of scientificity, where the fields of knowledge are separated, if we compare the natural sciences with the social sciences, we will see that there is no absolute difference between them. Furthermore, there are intermediate and transition areas between the two fields. This is the case of ecology, certain domains of biology, comparative psychology, etc., which can very well be seen as fields of knowledge of the natural sciences where knowledge of the human sciences is also required. This also refers to the classification model to which current sciences are subject. It presupposes a separation between subject and object, something that does not happen in the scientific fields mentioned as if we had a shadow, and a superposition between the two fields.

In the field of human and social sciences, contrary to what Augusto Comte (1798-1857) and the positivists thought, it is impossible to separate knowledge from value judgments. Michael Löwy even uses a physical metaphor to characterize this problem. According to him, the closer a natural science approaches the border with the social sciences, it becomes increasingly ideologically heated and becomes charged with ideological electricity.

Despite this epistemological impossibility, positivism continues to base its analysis on the model of objectivity that denies there is a substantial difference between natural and human sciences. According to positivists, the laws that govern social development are similar to the laws of nature and, therefore, social sciences dissolve in the natural environment.

In general terms, some methodological differences exist between natural and social sciences and the main ones are the following:

1) The historical character of social and cultural phenomena, and the possibility of them being transformed by the actions of men, which does not happen with the laws of nature where human action aims to know them in order to better use them.

2) A certain identity, sometimes partial and often even a fusion between subject and object in the social sciences, raises the possibility of a new system of classification of sciences.

3) Social classes interpret the past and present, social and political conflicts in terms of their social lives and experiences, their interests, aspirations, which makes historical sciences inseparable from value judgments.

4) Knowledge or recognition of the truth can have profound consequences on the behavior of social classes and consequently on the correlation of forces in social and political conflicts. Revealing or hiding the truth is a political weapon in the context of the class struggle. It is in this context that Antonio Gramsci (1891-1937) stated that *truth is always revolutionary*.

The reasons listed above make the method of social sciences different from that of natural sciences. This makes the problem or model of objectivity in the two fields of knowledge completely different. As already emphasized and discussed previously, the issue of ideology continues to be the central problem that makes the difference between the two scientific fields.

There finally remains a delicate issue to be resolved. As mentioned in item c, if it is not possible to separate objective knowledge from its value judgments, how can we escape the positivist trap without falling into relativism in the social sciences? There is only one possible solution, which is to propose that knowledge placed from the perspective of the subordinate and exploited classes has a greater chance of being closer to the truth. However, this question remains crucial for the social sciences.

8. Some Differences between Scientific Knowledge and Technological Knowledge

Recently, a discipline called *Philosophy of Technology* (Feenberg, 1991) has been created, with the purpose, among others, of highlighting the specificities of technological knowledge compared to scientific knowledge, and in this way, expanding our understanding of the production of knowledge in general. Underlying this vision is the conviction that not all sources of true knowledge come from science.

With the aim of highlighting some differences between science and technology, we will present some of them below:

1) Technology, although it can apply scientific knowledge, cannot be confused with it.

Most likely, the majority thought about technology, even among scientists and technologists, is understood as an application of science. This, in fact, in many cases is what actually happens, but it is a very simplified view of the problem. In this simplistic view, science provides the raw material and technology is a mere modus operandi and a matter of seeking an application in the form of a product or service. This view hides a very complex relationship between S&T, with multiple interactions and causation. Both scientific production is highly technified, in the form of sophisticated laboratories and very complex operating instruments, and technology is also quite intensive in scientific knowledge, simply monitoring what is happening with new technologies, such as nanotechnology and others. It is no coincidence that the term technoscience already exists to characterize this interaction, almost a fusion.

2) Technological knowledge is quite "sui generis" and is configured as the "science of the artificial".

In general, technology can also be characterized as a "science of the artificial", here the term presents itself as an opposition to the knowledge of the natural world, transformed by man, but not created by him[7]. The artificial constitutes a system adapted to the environment with a certain human purpose, to produce an artifact with desired properties, idealized in advance and then designed and manufactured. This type of knowledge can be qualified as "prescriptive knowledge", in contrast to the "descriptive knowledge", sought by science (Cupani, 2006).

3) The objectives are different between science and technology.

[7]Marx, in footnote 89, of Book I of Capital, draws attention and makes the distinction between a natural History and a Social History, establishing a comparison between a technology of natural organs and another constructed by social man, and which would be a technology of artificial things. Modernly, the term artificial technology has been used as a technology of things, when we refer, for example, to an internet of things (IoT). Marx states: *Darwin interested us in the history of natural technology, in the formation of organs, plants and animals as instruments of production necessary for the life of plants and animals. Does not the history of the formation of the productive organs of social man, which constitute the material basis of all social organization, deserve equal attention? And is it no longer possible to reconstitute it since, as Vico says, human history is distinguished from natural history, because we have done one and not the other?*

The primary objective of science is to establish laws that govern natural phenomena, such as the laws of body movement, the law of body expansion, etc.; In the case of social systems, these laws have more of a tendentious character, being subject to the conscience and will of groups or social classes. The objective of technology is more focused on formulating rules of action to give rise to artificial phenomena, although these rules may even derive from these laws.

9. Undoing Some Technological Myths[8]

MYTH No. 1: *Technology serves to reduce the workload and make people's lives easier.*

Right at the beginning of Chapter XIII, of the first book of Capital, whose title is: *Machinery and Modern Industry*, in item 1. *Development of Machinery*, Marx (1818-1883) quotes a phrase taken from the work *Principles of Political Economy*, written by John Stuart Mill (1806-1873).

It is doubtful whether the mechanical inventions made up to now have relieved the daily toil of any human being.

Marx, although he generally agrees with the above statement, however, makes a small note that this human being does not live off the work of others. And Marx adds:

This is not the objective of capital when it employs machinery. This employment, like any other development of the productive power of labor, has the aim of making goods cheaper, shortening the part of the working day that the worker needs for himself, in order to increase the other part that he freely gives to the capitalist. Machinery is a means of producing added value (Capital, Book I, Chapter XIII).

In the quote above is the key to understanding the role of technology in capitalist production. Since the use of labor force is a commodity, the cheaper use of new technologies, in short, technological innovation, has this purpose and pays less for its use. A few pages later Marx states:

From the exclusive point of view of making the product cheaper, the application of the machine must be contained within the limit in which its own production requires less labor than what it replaces with its application. For capital, however, the limit is tighter. Since it does not pay for the work employed, but

[8]The origin of myths lies in the attempt to explain the facts of the natural and cultural world. In this way, the myth itself always fulfills a social function that is that of explanation, and it is in this way that a certain narrative is constructed, and, depending on the power of imagination, they can acquire credibility in their explanation and crystallize in lasting way. Myth also reflects the way in which the real world is perceived by different peoples and cultures, and, in turn, this modified reality is reflected in the myths themselves. Thus, historians and philosophers of science are busy, in the incessant search to know and interpret the world. Many historians have drawn attention to the importance of myths, especially in Greek culture, where they emerged, and have no doubt in stating that they are at the origin and core of the tradition of Greek philosophy.

The meaning of the myth used in this paper, especially with regard to the so-called "technological myths", expresses a very widespread opinion, but like all myths, it is an alternative narrative and does not always match the reality of the facts, as long as it is seen under another point seen with greater explanatory power and better substantiated.

the value of the labor force used, the application of machinery, for capital, is limited by the difference between the value of the machine and the value of the labor force it replaces (Capital, Book I, Chapter XIII).

Marx further enriches this discussion of the expansion of machinery during the Industrial Revolution, stating:

Making muscular strength superfluous, machinery allows the employment of workers without muscular strength or with incomplete physical development, but with more flexible limbs. Therefore, the capitalist's first concern when employing machinery was to use the work of women and children. Thus, from a powerful means of replacing work and workers, machinery immediately transformed itself into a means of increasing the number of employees, placing all members of the worker's family, without distinction of sex and age, under the direct rule of capital) (Capital, Book I, Chapter XIII).

In short, the use of technology, as Marx exemplified when referring to widespread mechanization during the period of full development of the Industrial Revolution in England, had the purpose of increasing the dominance of capital over labor, lowering the value of wages and increasing more relative value, including women and children whose wages were even lower than that of a common worker, in addition to increasing the number of workers available for production, which put even more downward pressure on wages.

MYTH No. 2: *Technological innovation is made by genius entrepreneurs responsible for revolutionary inventions*.

It is extremely important to consider the real role played by government investments in the scientific and technological development of any advanced country. Certain myths widely spread by the media that the wonders that have emerged in the electronic goods and services market, for example, are due solely and exclusively to individual entrepreneurial capacity, combined with other characteristics such as genius, capacity for insight, etc. We will show, even briefly, that this is a myth.

Let's start with an example in the USA. In 1945, Vannevar Bush (1890-1974), advisor for scientific affairs to then-president Franklin Roosevelt (1882-1945), sent him a report entitled: *Science, the endless frontier*, in which he suggested that the government adopt a collaborative model of technological innovation, mounted on the tripod: State, University and Companies. The first agent would be responsible for financing the innovative initiative, the second would be responsible for research into new technologies and, finally, the companies for their development and transformation into a final product. This system has obviously undergone many changes over the years, universities have in some cases been replaced by companies' own research centers, but public investments have always been fundamental to the current stage of technological development that we have reached today.

To exemplify, we will use three quotes taken from the book by the professor of Innovation Economics at the University of Sussex (Mazzucato, 2013):

1) About the role of public financing in the launch of iPads and iPhones:

But without the massive public investment behind the computer and internet revolutions, these (individual) attributes might have led only to the invention of a new toy and not revolutionary products like the iPad and iPhone, which changed the way people live. People work and communicate (Mazzucato, 2013, Chapter 5).

2) Regarding Denmark's leading role in the field of wind energy, recently exceeding its internal demand by 40%, being able to export energy to Germany, Sweden, and Norway:

The Danish push into wind turbines included state-funded prototype development, which attracted major manufacturers. Companies like Bonus and Vestas were able to buy patents generated by the Danish research program and small pioneering companies, which gave them control over collective knowledge (Mazzucato, 2013, Chapter 7).

3) On the progress made by photovoltaic solar energy:

Bell Labs had invented the first crystalline silicon (C-Si) photovoltaic solar cell in 1954 *while still part of AT&T. The first major opportunities for solar photovoltaic technology were created by the Department of Defense and NASA, which purchased solar cells produced by the American Hoffman Electronics for artificial satellites* (Mazzucato, 2013, Chapter 7).

In short, the forms of government financing can be varied, direct financing in projects, or only in the crucial phase of developing a prototype, or even guaranteeing the purchase of products.

MYTH No. 3: *S&T are neither good nor bad, their applications can be beneficial or harmful to human beings.*

The above statement constitutes one of the most widespread myths among broad segments of the population or even by scientists and scientific researchers. In order to remove from the shoulders of science and technology any possibility or any culpability for harm caused by wars, weapons of destruction of any nature, people forget that both science and technology are produced in the social and political space of this society, which both have fundamental vectors for economic production. We must also add that there is no idealized science in its pure state and that the problem lies solely in the application. Sometimes, to reinforce this line of argument, the case of a knife is cited that can be used to cut a vegetable, a fruit, etc., but can also be used to kill, reinforcing the thesis that the use is what makes the difference and not the technology itself.

What we want to say is that S&T are a preponderant part and are at the center of economic production, serving its mediate and immediate purposes and the policies and strategies of the capitalist system at a global level. A knife is linked to a specific person and serves the will of its owner. S&T serves large capitalist corporations and their governments, representing a social and political force and the knife is deprived of this power and social insertion.

In capitalist society, with the widespread production of goods, the science that is produced is practically all aimed at increasing the profits of enterprises and even a so-called pure science, that is, one that does not have a short horizon of application, is completely conditioned by productivism criteria and increasing efficiency. In the case of the most developed countries, especially the USA, the entire scientific and technological apparatus is supported by the arms industry and the policies of large corporations. Other industrial segments, such as the food industry or medicine manufacturing, serve the greater objectives of capitalism: to grow and increase profits. It is precisely in this case that public investments stand out and support technological production precisely at that stage in which private interests do not make the necessary investments given the high degree of uncertainty about their return. This is what we recently saw in the manufacturing of vaccines against Covid-19. And what's worse, most of the time the public sectors that made these investments are hardly compensated at all for the investments made, much less society, when those investments resulted in major technological innovations. In capitalist society, the sectors that produce value are not always compensated and the appropriation of the value produced is redirected to other segments of society that have the political power to do so.

10. Final Comments and Conclusion

In this paper, we tried to bring together the points that seemed most important to us for a more general and systematized characterization of the nature of scientific and technological knowledge. We also try to differentiate scientific knowledge from technological knowledge, although in many branches of knowledge this is a more complicated task, such is the symbiosis between both. In some cases, this differentiation is even unnecessary.

As a new classification of sciences is increasingly required, the current classification based on the separation between subject and object is presenting more problems in incorporating new fields of knowledge. As an example, we would like to highlight the increasingly important role of the development of neuroscience, moving in the same direction of building a new vision of the subject-object relationship in even older branches of science, such as economics. On the other hand, due to the importance of the subject in the construction of scientific knowledge, studies in the field of the subject's interaction with the world and the formation of their worldview, closely related to their social practice (work) must, with all certainty, be one of the most promising fields in terms of increasingly revealing the nature of scientific knowledge[9].

In the field of social sciences and not strictly in economics, the importance of the subject of knowledge is also becoming more important, as pseudo-neutrality

[9]We think that future research aimed at increasingly revealing science as an object of study, where its nature is a fundamental part and which attempts to generalize the various particular knowledge by building a unified version of them all, will also always present a dimension provisional, since this particular knowledge also has this dimension. How scientific knowledge is entirely constructed by the subject. We would point to the psychology of knowledge, neuroscience, and related disciplines as the privileged fields for advancing how the subject constructs this knowledge in the context of their practice immersed in the natural and social world.

is left behind, indicating that the path to greater political and ethical engagement can provide these sciences with a better way of approaching "factual reality", adopting as a method the possibility of incorporating value judgments instead of trying to exclude them.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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