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MATHEMATICAL IN THE CONSTRUCTION OF MODERN SCIENCE

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Abstract: The present study aimed to: demonstrate that with the history of science it is clear that mathematics guided the type of knowledge that was developed in the 17th century and that created the scientific method that predominates to this day. Explain the scientific method by relating it to philosophers: mathematical knowledge at the foundation of the paradigm of the Scientific Revolution of the 17th century. Readings, analysis and interpretation of the authors were carried out and the following items were addressed: science, philosophers, scientific revolution. This research was carried out from February to June 2016. Modern science is characterized by a mental or intellectual attitude through two traits that complement each other: 1) the destruction of the cosmos and consequently the disappearance in science. 2) The geometrization of space, that is, the replacement by the homogeneous and abstract space of Euclidean geometry of the conception of a space in pre-Galilean physics. It can be expressed in: the mathematization (geometrization) of nature and, consequently, the mathematization of science. This implies the disappearance of the scientific perspective, of all considerations based on value, perfection, harmony, meaning and design. Such considerations disappear in the infinite space of the new Universe and, it is in this new world, where geometry becomes reality, that the laws of classical physics find value and application. This way of thinking, which characterizes the period in which scientific knowledge has been growing, does not take into consideration, the study of the whole, but analyzes its parts. Knowledge of the properties of the parts, however, does not lead to knowledge of the whole. Therefore, the science that reduces the complex environment to its parts is a source of violence, as it allows experts to act on the environment in just some of its parts, forgetting the connections between them. The transition from Aristotelian Physics to the classical Physics of Galileo and Newton occurs through the transformation of qualities into quantities, concluding that science would be more rigorous the more mathematizable it was. Modern science will compare nature and man himself to a machine, a set of mechanisms whose (mathematical) laws need to be discovered.

Keywords: mathematics; knowledge; history; science.

INTRODUCTION

Scientific knowledge is a recent achievement of humanity: it is only three hundred years old and emerged in the 17th century with the Galilean Revolution. However, we know that Greek science is still linked to philosophy and only separates itself from it when it seeks its own path, that is, its method, which will only occur in the Modern Age. To be precise and objective, science has a rigorous language, whose concepts are defined in order to avoid ambiguities. This language becomes increasingly precise, as it uses mathematics to transform qualities into quantities.

The question that arises is how to explain to students the importance of mathematics in today's world, since mathematics appears as a complement to other subjects, and when taken out of context it appears to be meaningless. The division of disciplines that advances as a result of capitalist development seems to take away its essence.

In view of the above, the present study aims to:

i) Demonstrate that with the history of science we realize that mathematics will guide the type of knowledge that was being developed in the 17th century and that will elaborate the scientific method that predominates to this day.

ii) Explain the scientific method by relating it to the philosophers: Galileo

Galilei; Rene Descartes; Francis Bacon and Isaac Newton and with their mathematical knowledge in founding the paradigm of the Scientific Revolution of the 17th century.

It is necessary to recognize that our teaching is usually carried out in a very ahistorical way. There are few who are concerned with using history as a guiding thread in the transmission of different knowledge.

DEVELOPMENT

SCIENCE

"Ancient and medieval science was a theoretical science, it only contemplated beings, without ever imagining the possibility of intervening in them or on them. Technique was empirical knowledge, linked to the practices necessary for life and had nothing to offer science or receive from it" (MARTINS, 1991, p. 126). According to Aranha (1993), for the Greeks, there is knowledge that involves both the knowledge of its particulars (science) and the knowledge of being as being (metaphysics). This means that this science lacks its own method that distinguishes it from philosophy. Pythagoras of Samos considered number the arché of all things. From this derives the harmony of nature, made in the image of the harmony of number. These concerns lead the Greeks to a theoretical construction made by Thales of Miletus (VI b.c.) and Euclid (III b.c.), in whose elements he systematizes theoretical knowledge, giving them the foundations. Thus, for example, it starts from primitive concepts such as the point, the straight line and the plane, which are not defined, and from postulates (example: "a point outside a straight line only passes one parallel to that straight line") that cannot be defined. demonstrates, but which are the starting point on which the theoretical edifice of every demonstration is built. Another science that developed among the Greeks was mechanics, the foundations of which were given by Archimedes in the (3rd century BC). Through this technical activity, fundamental principles of mechanics can be discovered: he wrote a treatise on statics, formulated the law of balance of levers and carried out studies on the center of gravity of bodies.

What we noticed is that in the Greek conception of science, there is a devaluation of manual work, of the technique of doing it itself. Intellectual activity, theory, is considered superior and dissociated from practice. However, we know that great thinkers have turned their attention to theory throughout history. According to Martins (1991), Plato placed science at the forefront of all intellectual activity. He was interested in the principles, methods and progress of mathematics, physics, astronomy and biology. He himself formulated bold hypotheses about the laws that govern them. He greatly admired mathematics for being a deductive science, having formulated ideas about negative numbers and the method of variations.

Aristotle already associated science with practice, "science is based on definition and demonstration" (CHASSOT, 2001), the philosophy of nature, the principles of existence are addressed: matter and form, movement, time and space. It is through the notion of matter and form that movement is explained. Every being tends to act (make actual) the form it has within itself as potential, the passage from potency to act. Movement is the act of a potential being, as such is the potency updating itself. According to Aranha (1993), for the Greeks what needs to be explained is movement: the natural order can be altered by a violent movement caused by the application of an external form.

Martins (1991) requires an artificial explanation from Aristotle: when throwing a stone, the hand communicates its own power to the air near it, causing a whirlwind that keeps the stone in motion; This power communicates through contiguity and - because the intensity decreases with each transmission, the movement ends up ceasing, and through natural movement the body returns to its natural place. Behind these statements there are a series of metaphysical notions regarding the nature of bodies and movement that need to be clarified. Every being is made up of matter and form, inseparable principles, while form is the intellectual principle common to individuals of the same species, matter is pure passivity, containing potential form. As we can see, when Aristotle talks about movement he is not just referring to the concept of local movement, movement can also be understood as qualitative movement, whereby the body has an altered quality or even quantitative movement. As Aranha (1993) highlights, the Aristotelian conception of nature is, therefore, finalist or theological (telos, "end"). "Nature is what tends towards an end, in continuous movement, by virtue of an imminent principle." Thus, the heavy body tends to transform into a tree; the roots go into the soil to nourish the plant, etc.

Martins (1991), states that the Greeks will also try for the first time to rationally explain the movement of the stars, although there remains in these explanations a certain mystique of the perfection of the eternity of rest and the choice of the circle as the perfect shape: hence uniform movement is considered perfect, always identical to itself, and therefore immutable and eternal. Circular motion has no beginning or end; it comes back on itself and always continues, it is movement without change. Added to this is the conception of a finite universe, limited by the expectation of heaven, outside of which there is no place, no vacuum and no time. Another important feature in Aristotelian cosmology is the hierarchy by which the nature of the sky is considered superior to the nature of the earth. The universe would be divided into:

- supralunar world, constituted by the "heavens".

- sublunary world, corresponding to the "earth" region.

From this division we realize that the Greeks associate perfection with balance, with rest, and that the description of the cosmos is that of a static world. Even in the world of mutations, science aspires to this ideal of immobility, searching behind the changing appearances of things for the immutable essences. According to Aranha (1993), Aristotelian physics is qualitative, because it is built on the principles that define things, from which consequences are deduced. It is about valuing the deductive method, whose powerful model is found in mathematics. Despite this, the Greeks did not mathematize physics. Likewise, Aristotle does not appeal to experience. He starts from the common observation: "the stone falls" and asks "why?" and not "how". If he asked this last question, he would proceed to describe the phenomenon. But asking "why?", he embarks on a search for causes, inevitably leading to a metaphysical discussion of the essence of bodies and the finalist perspective. Therefore, Aristotelian science is philosophical, centered on argumentation based on principles.

According to Aranha (1993), in the 12th century, translations of the works of Archimedes, Hero of Alexandria, Euclid, Aristotle and Ptolemy began to appear. The thoughts of these authors often arrived in Europe distorted, as they were translated from Greek into Syrian, from Syrian into Arabic, from Arabic into Hebrew and from Hebrew into medieval Latin. Science is focused on rational and continuous discussion, disconnected from technique and empirical inquiry. Medieval science is not experimental, nor does it use mathematics, it remains qualitative, as in Antiquity, as the available mathematics resources are still incipient. The use of Arabic numerals is not widespread, so it remains customary to use Roman numerals. This makes calculations difficult, which can be observed, for example, in the division of MDCXXXII by IV, which is impossible to solve without the help of an abacus, a planchette equipped with balls.

Exceptions to the medieval tradition arose, such as Roger Bacon (13th century), persecuted on several occasions due to ideas that were not well suited to the scholastic world, in addition to seeking to apply the mathematical method to natural science, he made several attempts to make them experimental, especially in the field of optics. According to Martins (1991), another exception in the Middle Ages is the contribution of the Arabs. In their expansionist movement, the Arabs learned about Greek culture and began to disseminate it through translations and the creation of study centers. In the field of science, they transmit ancient knowledge. In mathematics, they are the introducers, in the West, of Arabic numerals and are the creators of algebra. In astronomy, they improved trigonometric methods for calculating the orbits of the planets, even introducing the concept of sine.

Based on Aranha (1993), in the medieval world there was a reluctance to incorporate attempts at experimentation and mathematization of natural sciences. Concern about life after death makes interest in religious discussions prevail. Even when we ask for help from philosophizing reason, it is still revelation that appears as a criterion of truth in the production of knowledge. The principle of authority, that is, the blind acceptance of the "truths" contained in the biblical text and in the books of great men, especially Aristotle, prevents any innovation. And the obscure phase of magister dixit which, in Latin, means "The master said". The rigor of this control is felt in the judgments made by the Holy Office (Inquisition), a Church body that examined the heretical nature or otherwise of doctrines. Depending on the case, the works were placed on the Index, a list of prohibited works.

Chauí (1991) draws attention to two statements that show the differences of modern people in relation to the ancients, the statement of the English philosopher Francis Bacon, for whom "knowledge is power", and the statement of Descartes for whom "science must become in the lords of nature." Greek science is linked to philosophy and only separates itself from it when it seeks its own path, that is, with the scientific method. According to Sevcenko (1986), the development of an attitude that today could be called scientific must be understood, therefore, as an inseparable aspect of the entire Renaissance culture. If with the astrologer Copernicus, astronomy and cosmology were still a theoretical field more explored by mathematics and deductive reflection, with the astrologers Tycho Brake and Kepler just over 50 years later, they were already the object of systematic observations supported by instruments and bold experiments. The same evolution occurs in other domains of knowledge: Vesalius lays the foundations of modern anatomy, William Harvey, little hampered by "superstition" or the veneration of "antique" theories, demonstrates the mechanism of blood circulation through direct observation and empirical proof. Leonardo da Vinci carries out theoretical research and practical projects in the field of hydraulics and hydrostatics: the same does Brunelleschi with architecture and construction techniques.

There are multiple paths of Renaissance thought and certainly the variety, the plurality of points of view and opinions, was one of the most notable factors in its fertility. Most of the trails that were opened there, we still follow today. The dispute, the controversies, the criticisms between these creators are intense and heated, but they all eagerly follow Pico Della Mirandola's lesson: man's dignity rests in the depths of his freedom.

THE PHILOSOPHERS WHO CONTRIBUTED TO THE SCIENTIFIC REVOLUTION OF THE 17TH CENTURY

GALILEU GALILEI

> Philosophy is written in this great book that continually opens before our eyes (that is, the universe) that we cannot understand before understanding the language and knowing the characters in which it is written. It is written in mathematical language, the characters are triangles, circles and other geometric figures, without which it is impossible to humanly understand the words; without them we wander lost within an obscure labyrinth. (GALILEI, 1973, p. 119)

According to Chauí (1984), Galileo was perhaps the first spirit to believe that mathematical forms were effectively realized in the world. Everything that exists in the world is subject to geometric form; all movements are subject to mathematical laws, not only regular movements and regular shapes, which may be absolutely non-existent in nature, but also irregular shapes. Irregular shape is as geometric as regular shape; one is as precious as the other. The irregular shape is just more complex. The absence in nature of lines and perfect circles does not constitute an objection to the predominant role of mathematics in Physics. "Galileo is one of the exponents of the emergence of a new time: nascent science is not the result of evolution, but of a scientific revolution, of a rupture in the adoption of a new language" (MARTINS, 1991, p. 145).

This universal knowledge (method), the spirit of the new science, one could say inaugurated with Galileo, with the change in meaning transforms the human point of view. His vision was mathematical, Galileo combines experimentation with mathematics, he geometrizes space (lunette), which means that the heterogeneous space of natural places becomes homogeneous, is stripped of qualities and becomes quantitative, measurable. Proving that heaven and earth are of the same nature.

FRANCIS BACON

> The discoveries made so far are that they almost only rely on vulgar notions. In order to penetrate the deepest and most distinct strata of nature, it is necessary that both notions and axioms are abstracted from things by a more appropriate and safe method, so that the work of the intellect becomes better and more correct (BACON apud RANHA, 1994, p. 149).

The author Francis Bacon ranks among the main methodologists of scientific research using the inductive method. This type of reasoning starts from specific and observable facts to broad generalizations (DOWNS, 1969). According to Chassot, (2001), Bacon insists that one must take note not only of failures but also of successes, and observe a large number of cases. He defended inductive reasoning, a system that starts from specific and observable facts, with each step having to verify each generalization, look for possible exceptions and repeat or review the generalizations when such exceptions were found. With this method, he greatly accelerated the development of modern scientific theories. The deficiency attributed to him is the omission of the immense importance of mathematics in the study of natural phenomena.

Francis Bacon, cited by Aranha (1994), stated that to reach a reasonable knowledge of the world that surrounds him, man must, before anything else, get rid of all prejudiced notions and seek to carry out experiments that would form the basis of any and all learning. Through his method, Bacon came to gather a series of important data at his time, such as the notion that the amount of matter in the universe is constant. However, his lack of mathematical knowledge prevented further progress in his theories.

RENÉ DESCARTES

> Cartesian philosophy, in fact, is not just a philosophy that is strictly distinguished from science. It is at the same time a philosophy that systematically develops the philosophy-science opposition: the categories of thought and space (DESCARTES apud CHASSOT, 2001, p. 105).

According to Downs, (1969), Descartes, the greatest mathematician of his time, opened the way for the application of the mathematical method in the investigation of scientific problems. Descartes' first step was to reject all traditional opinions inherited from Antiquity and the Middle Ages, and through "methodical doubt" to eliminate everything that was vague, unworthy of credibility and imaginary. He proposed a systematic skepticism, which accepted nothing without challenge, except the existence of the skeptic himself. "I think therefore I am."

According to Chassot, (2001), Descartes concluded that the mathematical method was the ideal instrument to be applied in all spheres of knowledge and that it would give results of equal precision, and confidence in metaphysics, ethical logic. Consequently, he concluded that everything that cannot be translated into mathematical terms is unreal. According to this premise, the entire universe can be explained by the laws of mechanics and mathematics.

He introduced the procedure of locating a point in space through two straight lines that form a right angle to each other, still known today as the Cartesian coordinate system. We owe him the important association of geometry with algebra. Descartes, cited by Chassot, (2001), concluded that he lived in a world governed by mechanical forces. Descartes' world could be known mathematically, in terms of extension and movement. He considered as true only what was possible to intuit with clarity and evidence.

ISAAC NEWTON

> "If I have seen further than other men, it is because I have stood on the shoulders of giants." (NEWTON apud CHASSOT, 2001, p. 109)

According to Downs (1968), Isaac Newton elaborates the first example of scientific theory found in modern science: Universal gravitation theory. The laws formulated above refer only to particular aspects of the phenomena considered. The Newtonian system covers the entirety of a certain sector of reality and therefore carries out the greatest scientific synthesis about the nature of the physical world.

In Chauí's (1991) point of view, Newton studies the movements of bodies, treated mathematically; however, he studies more especially the application of the dynamics and universal gravitation of the solar system. The explanation of differential calculus, used in calculations throughout the work (Main), follows the definition of space and time, and the formulation of the law of motion. The latter contains the fundamental proposition that each particle of matter is attracted to each other particle of matter in a force proportionally inverse to the square of the distance that separates them. The formula is F = Gm1xm2/r2, where F is the gravitational force, G is the universal gravitational constant (a specific number, which is always the same), m1, m2 are the masses of the two bodies and r is the distance between them.

Newton, cited by Chassot, (2001),

recognized that the world system – the mechanics of the universe – was based on the work begun by Copernicus and so notably continued by Brahe, Kepler and Galileo. He showed that it was possible to understand and explain nature through mathematical formulas. He compares nature and man himself to a machine, a set of mechanisms whose laws were being discovered. The explanations are now based on a mechanical scheme whose model is the clock. Newton shows us how to use mathematics in the study of nature; later, he formulated the law of universal gravitation, explaining how movement occurred throughout the cosmos.

THE SCIENTIFIC REVOLUTION

Scientific knowledge is a recent achievement of humanity, it is only three hundred years old and emerged in the 17th century with the Galilean revolution (MARTINS, 1991). According to Chauí (1991), modern science was born linked to the idea of intervention in nature, of knowing it to appropriate it, to control and dominate it. Science is not just the contemplation of truth, but is, above all, the exercise of human power over nature. The scientific object is mathematical because reality has a mathematical structure.

Modern science, distinct from ancient science in several aspects, proposes a new association of those concepts. Technique was seen as a lesser form of knowledge, in a slave society that reserved tasks, jobs, and the most diverse services for slaves. According to Chauí (1991), in the 17th century, the word method (from the Greek: path, right, correct, safe) had a vague meaning and a precise meaning. Vague meaning because all philosophers have a method or their method, with as many methods as there are philosophers. Precise meaning, because the good method is the one that allows you to truly know the greatest number of things with the least number of rules. The greater the generality and simplicity of the method, the more it can be applied to the most different sectors of knowledge, the better it will be.

According to Aranha (1993), the method is always considered mathematical. This does not mean that arithmetic, algebra and geometry are used to understand all realities, but rather that the method seeks the mathematical ideal. This means two things:

> 1- That mathematics is taken in the Greek sense of the expression mathema, that is, complete, perfect knowledge and entirely dominated by intelligence (arithmetic, geometry, algebra is mathematics, as they completely and intellectually dominate their objectives.)
>
> 2- That the method has two fundamental elements of all mathematical knowledge: order and measure.

The Revolution of the 17th century brings the search for objectivity in the search for the necessary universal structures of the things investigated. This knowledge is quantitative, that is, they seek measurements, standards, evaluation and comparison criteria for things that appear to be different. It is also homogeneous, as it seeks general laws of functioning of phenomena that are the same for facts that seem different to us, under the laws the same standards or measurement criteria, showing that they have the same structure.

Chauí (1991), states that, through knowledge, man can free himself from fear and superstitions, allowing them to be projected onto the world and onto others. It seeks to continually renew and modify itself, avoiding the transformation of theories into doctrines and these into prejudices. The scientific fact results from patient and slow work of investigation and rational research, open to change, and is not an incomprehensible mystery nor a general doctrine about the world.

According to Martins (1991), science has a rigorous, precise and objective language, whose concepts are defined in a way that avoids ambiguities. This language becomes increasingly precise, as it uses mathematics to transform qualities into quantities. The mathematization of science begins with Galileo. When establishing the law of falling bodies, it measures the space and time that a body uses to travel an inclined plane. And the end of his observations is recorded in a mathematical formulation.

Modern science is based on observation and experimentation, making it more rigorous, precise and objective. Another important element is the use of measuring instruments (scales, thermometer, dynamometer) that allow the scientist to overcome the immediate and subjective perception of reality and carry out an objective verification of the phenomena. Formal and final causes are not only used to explain efficient causes, but are also used in scientific explanations.

FINAL CONSIDERATIONS

Chassot (2001), Martins (1991), Aranha (1993) and Chauí (1991) agree that modern Science characterizes the mental or intellectual attitude through two traits that complement each other:

> 1- The destruction of the Cosmos and consequently the disappearance in science of all considerations based on this notion.
>
> 2- The geometrization of space, that is, the replacement by the homogeneous and abstract space of Euclidean geometry of the conception of a space in pre-Galilean physics. These two characteristics can be summarized and expressed as follows: the mathematization (geometrization) of science.

Through these ideas, the disappearance, from the scientific perspective, of all considerations based on value, perfection, harmony, meaning and design is implied. Such considerations disappear in the infinite space of the new universe. It is in this new universe, in this new world, where geometry becomes reality, that the laws of classical physics find value and application. This way of thinking, which characterizes the period in which scientific knowledge has been growing, does not take into consideration, the study of the whole, but analyzes its parts. It requires not only that the whole be separated into parts, but also considers them more important than the whole. Knowledge of the properties of the parts, however, does not lead to knowledge of the whole.

Therefore, the science that reduces the complex environment to its parts is a source of violence, as it allows experts (specialists in a particular and restricted area of knowledge) to act on the environment in only some of its parts, forgetting the connections between them.

In the same way, Chassot, (2001), Aranha (1993), Martins (1991) and Chauí (1991), state that during more than 99% of the history of humanity, the conception that the world was enchanted and man became felt like an integral part of it. In the last four centuries, the total reversal of this conception destroyed, on a psychic and physical level, man's feeling of integration in relation to the cosmos. This was responsible for the near ecological destruction of the planet. The only hope, it seems to me, lies in the re-enchantment of the world as a means of our re-encounter.

Thus, science eliminates most of the sensual and aesthetic appearance of nature. Sunsets and waterfalls are described in terms of frequency of light rays, refraction coefficients and gravitational or hydrodynamic forces. By striving to be objective, science excludes any and all references to subjective, individual or collective experience. Therefore, modern science describes a world of valueless things, interacting as if humanity did not exist. But because the nature we experience is steeped in our evaluations, as in the terror of hurricanes, the calm of ponds, and the sweet, gentle sadness of falling leaves, the scientific description of nature remains cold, incomplete, and unsatisfactory.

Finally, science is freeing itself from the ideological ties of the European 17th century and seeking a more universal language, more respectful of other traditions and other issues. Perhaps in this renewed atmosphere we will see new forces in the encounter between our knowledge and our powers.

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