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REFLECTIONS ON DISINFORMATION AND FAKE NEWS FROM THE HISTORY OF SCIENCE: Lessons from Archimedes and Lavoisier

REFLEXÕES SOBRE DESINFORMAÇÃO E FAKE NEWS A PARTIR DA HISTÓRIA DA CIÊNCIA: Lições de Arquimedes e Lavoisier
REFLEXIONES SOBRE LA DESINFORMACIÓN Y LAS NOTICIAS FALSAS DESDE LA HISTORIA DE LA CIENCIA: lecciones de Arquímedes y Lavoisier

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ABSTRACT
This article aims to analyze the contemporary phenomenon of disinformation and fake news through lessons drawn from the history of science, specifically from the episodes of Archimedes' "burning mirrors" and the transition from alchemy to modern chemistry, led by the work of Lavoisier. The methodology consists of a historical and epistemological analysis, using dialectics as a tool to understand the overcoming of paradigms. The study of the burning mirrors case reveals how narratives can persist regardless of their factual veracity, serving as a metaphor for fake news that feed on fragments of truth. The analysis of the transition from alchemy to modern chemistry demonstrates how cohesive belief systems can resist anomalies for long periods, similar to contemporary scientific denialism. It is concluded that combating disinformation does not lie in the mere correction of facts, but in the promotion of critical education and a form of science popularization that is committed to its social purpose – "para quem te quero" ("who do I want you for"). Both must emphasize the dialectical process of knowledge construction – its uncertainties, contradictions, and self-correcting capacity. Thus, it is argued that initiatives such as the "Mais Ciência na Escola" Program and a science popularization committed to popular causes are fundamental to forming a society capable of thinking historically, systemically, and critically.

KEYWORDS: Disinformation. Fake News. History of Science. Epistemology. Science Education and Science Popularization.

Introduction

Disinformation, in its contemporary form, has taken on a markedly media-driven profile, propagated with considerable intensity through social media (Carvalho; Teixeira, 2024; Souza; Pôrto Jr., 2024; Silva; Silva, 2024). Its dissemination through digital platforms has produced profound and often negative impacts: wars, coups

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d'état, manipulation of public opinion, hate speech, among others. Democratic governments, attentive to this scenario, are intensifying the debate on regulation and the legal limits of freedom of expression (Pôrto Jr. et al., 2024a; Pôrto Jr. et al., 2024b; Pôrto Jr. et al., 2024c; Pôrto Jr. et al., 2025a; Pôrto Jr. et al., 2025b; Pôrto Jr. et al., 2025c).

One example is the National Network to Combat Disinformation, which brings together over 200 institutions and has developed projects such as SERICS/SPOKE 2, based at the University of Salerno in Italy. This is a multinational program that integrates different countries and seeks to contribute to both scientific investigation and technological innovation in the fight against disinformation (Guazina; Amoretti, 2024).

Despite the media-driven character that disinformation assumes in our days, lying is a strategy of self-preservation used since antiquity. As Machiavelli stated, "in certain situations, pretending, omitting, or even lying can be a legitimate defense" (Maquiavel, 2010). If lying is often used in human relations to deceive or self-preserve, in science it is not tolerated. This does not mean that everything that is, or has been, published is a certificate of truth. Science is a social practice, carried out by human beings and, therefore, subject to methodological and interpretative errors. Thus, science tolerates error and tries to correct it in its construction process, but it rejects, intransigently, lying. It is in this sense that the history of science can teach us some lessons to deal with the lies, disinformation, and Fake News that so compromise us today.

Even though the search for truth and objectivity have been recommended for the doing of science, both have been questioned by philosophers, the human sciences (Kuhn, 1991; Santos, 2014) as well as by the theoretical framework of the Biology of Knowing (Maturana, 1997; Maturana; Varela, 1995; Varela et al. 2003). Thus, by observing how paradigms are constructed, deconstructed, and reconstructed over the centuries, we better understand the pitfalls, paradigmatic ruptures, and advances suffered in all areas of science (Kuhn, 1991).

From this initial positioning, our objective is to learn from the lessons of the history of science, especially from Archimedes (3rd century BC) and Lavoisier (18th century), observing how science faced uncertainties and errors and how such confrontations can inspire us today in the fight against disinformation. To this end, we will take as examples two passages from the history of science, referred to here as Lessons, one analyzed by Pierre Thuillier in the book "De Arquimedes a Einstein – A

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face oculta da invenção científica" (1994), and the other in the transition from Alchemy to Modern Chemistry (MAAR, 1999).

On uncertainties and certainties in Science

Here we show how scientific theories travel a long path until they are accepted and how they can also be rejected when better explanations arise for the studied phenomena. To exemplify this statement, we will transcribe the controversy, studied by Thuillier (1994), surrounding the "burning mirrors" attributed to the great philosopher Archimedes during the siege of Syracuse. This historical account is considered an open question to this day, and underlying it is the question: is it a fact or a great "Fake News" from Antiquity?

Based on the in-depth analysis by Thuillier (1994), we will discuss how the history of science and also epistemology can offer analytical tools to understand and confront disinformation in the field of Sciences and how this can be used in the field of Education. We say this because Thuillier's study (1994) dialogues with our academic research regarding the use of scientific concepts in science teaching and science popularization. As a great historian of science, Thuillier (1994), in his study, shows us the various paths, obstacles, and shortcuts experienced by important scientists and philosophers from various eras regarding the studied case. A synthetic way to understand these historical paths and conceptual evolution in various areas of knowledge is presented by Andrade (2019) with the expression "conceptual landscape." The aforementioned author discusses the different meanings of the term concept, from which he allows the observer a double gaze: towards the past and the future:

> We analyzed the different meanings expressed for the term concept and, from a synthesis, built an original formulation for the concept of concept, metaphorically called here a conceptual landscape. [...] By allowing the observer a double gaze, towards the past and the future, they can become a good cartographic guide for theoretical displacements, research and teaching projects, contributing to teaching activity and the socialization of knowledge (Andrade, 2019).

By using the metaphor of the "path" to situate the student in the long process of the construction of the sciences, Andrade proposed that this metaphorical path occasionally opens onto landscapes — moments of reflection and provisional synthesis,

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unfinished and constantly restarting (Sancovschi; Kastrup, 2008), which he called conceptual landscapes (Andrade, 2019).

Thuillier's text (1994) is a good example to highlight these landscapes, showing how the history of science is not linear nor cumulative and is full of doubts, advances, and setbacks, corroborating what was proposed by Thomas Kuhn in his classic "The Structure of Scientific Revolutions" (1991).

Thus, Archimedes was, besides a philosopher, a mathematician, astronomer, physicist, and engineer. There is even a consensus among several historians of science when they state that the genius of the aforementioned philosopher finds a parallel only with Isaac Newton (1643-1727), born many centuries later.

Archimedes was born in the 3rd century BC in Syracuse, a Greek colony in Sicily. He studied at the Library of Alexandria and became famous for his discoveries applied to daily life, including war.

Among his most famous feats is the story of King Hiero II's "golden crown," reported by Vitruvius (80 BC – 15 BC). Challenged to discover if the goldsmith had adulterated the gold alloy of the crown, Archimedes realized, upon entering a bathtub, that the volume of displaced water was proportional to his own volume. Thus he discovered the principle of buoyancy, the foundation of hydrostatics, and solved the great enigma he was challenged with. The scene of Archimedes demonstrating his euphoria after the discovery is described jokingly - a naked man, running through the streets of Syracuse, shouting "Eureka, Eureka." Other notable contributions include the "Archimedes' screw," a spiral mechanism still used today for irrigation, as well as studies on levers, geometry, mechanics, and the quadrature of the circle — which anticipated the concept of the number π. His fame crossed generations in different regions and peoples, especially the Greeks, Romans, and Arabs, who preserved accounts of his discoveries, making him immortal.

Episode 1 - Archimedes and the burning mirrors: a lesson from the history of Science

During the siege of Syracuse in 212 BC, one of the most controversial stories in ancient science emerged, linked to the name of Archimedes: the so-called "burning mirrors." According to some narratives, Archimedes would have positioned large mirrors to reflect the sun's rays and set the Roman ships on fire. This episode, shrouded in mystery and disputes, generated controversies and even experimental simulations

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over the centuries, dividing scholars between those who considered the phenomenon a myth and those who defended its veracity. Interestingly, this question remains open.

Pierre Thuillier, in *De Arquimedes a Einstein* (1994), uses the siege of Syracuse as a paradigmatic example of the tension between myth and science. He analyzes historical accounts, opinions of scientists, and experimental attempts that sought to confirm or refute the efficiency of the burning mirrors. The author shows that, in the face of doubt, this narrative mobilized scientific and philosophical reflection for centuries.

To understand the debate, we organized two Tables (1 and 2) with information extracted from the book by the aforementioned author. They summarize the main arguments against and in favor of the plausibility of the existence of the burning mirrors.

Table 1
Authors who consider the event to be a myth

YEAR	SCIENTIST / HISTORIAN	ARGUMENT
1st century A.D.	Polybius, Livy and Plutarch	Lack of historical citations about the phenomenon.
1630	Descartes	The rays of the sun are not exactly parallel, and a burning mirror capable of acting at great distances would need to be excessively large.
18th century	Du Fay	Conducted experiments with a concave mirror and with a parabolic one, but the results were negative.
1977	D. L. Simms	There was neither the knowledge nor the technology required for the production of such mirrors, in addition to the silence of authors from that period.

Source: Authors, based on Thuillier (1994), with slight modifications.

Table 2
Authors who consider the Event to be plausible

YEAR	SCIENTIST / HISTORIAN	ARGUMENT
6th century A.D.	Anthemius of Tralles	Historian; held a favorable position.
1130	Zonaras	Defends a correlating fact by stating that Proclus used burning mirrors to destroy General Vitalianus's fleet when he besieged Constantinople in A.D. 514.
1294	Roger Bacon	Asserted that with a well-designed concave mirror, one could burn anything.
1551	Oronce Fine	Constructed burning mirrors with his own hands; wrote a book affirming that the parabolic mirror is more effective than the spherical one.
1632	Jesuit Bonaventura Cavalieri	Historian; wrote a treatise on the subject,

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		defending the thesis.
1646	Father Athanasius Kircher	Conducted experiments and found that five well-arranged flat mirrors produced almost unbearable heat.
1747	Buffon	Built a device with 168 small glass mirrors and tested the heat produced on various materials, concluding that Descartes was mistaken.
12th century	Ioannis Tzetzes, Byzantine autor	Describes the episode based on Dio Cassius, who had written about it in the 2nd century A.D.
12th century	Bishop Eustathius	In his commentary on Homer's *Iliad*, states that Archimedes, through an invention based on optics, set enemy ships on fire.

Source: Authors, based on Thuillier (1994), with slight modifications.

Tables 1 and 2 show that the controversy is not recent. While critics like Descartes (1596-1630) and Simms (1998) affirm the technical impossibility and the absence of historical accounts confirming the Event, experiments like those of Buffon in the 18th century and Ioannis Sakkas (a Greek engineer who reproduced the experiment in 1973) demonstrated, empirically, that well-positioned mirrors can indeed ignite wood. The question, however, remains: would it be possible to apply this resource in a real battle, with moving ships and under non-ideal atmospheric conditions?

At the end of his analysis, Thuillier (1994) proposes an epistemological reflection based on the episode of the burning mirrors, namely: science coexists with errors and subjectivities that intertwine in the process of knowledge construction.

Episode 2 - Phlogiston and the epistemological lessons derived from Lavoisier's Oxygen Theory

The Theory of Combustion is considered a masterpiece of scientific methodology for explaining the most impactful phenomenon in human history – fire (MAAR, 1999). From the hominids who used it in various moments of daily life, especially in protecting the shelter and preparing food, to the most abstract and beautiful philosophical and poetic reflection, carried out by the nocturnal Bachelard when describing the burning of a candle (Bachelard, 1989), fire has always fascinated us.

Having said that, we will now proceed to the historical-epistemological analysis of the construction of the concepts that led to the Theory of Combustion, which marked the emergence of Modern Chemistry.

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Our framing of the problem can begin with the alchemist Paracelsus (1493–1541) who believed that the "sulfurous principle" was responsible for the combustibility of materials. Becher (1635-1682), a disciple of Paracelsus, believed that there were three types of earth: *vitrifiable, mercurial, and pinguis,* with the latter being related to combustion. Following this idea, George Stahl (1660-1734), a disciple of Becher, refined this postulate by identifying the terra pinguis as a fatty, oily, and combustible earth, similar to Paracelsus's sulfurous principle. It would be responsible for the combustion power of substances. This principle was later named by Stahl as "phlogiston" or "the principle of fire." The term phlogiston comes from the Greek, *phlogiston*, which means to inflame. It should be noted that it is not fire in act, but in potential. That is, every substance that can combust contains phlogiston. It follows from this argument that when a substance catches fire, it loses phlogiston (Bell, 2007).

Although Stahl's theory of phlogiston explained a large part of the empirical observations about combustion, an important contradiction arose when the reactants were quantified. Thus, in some reactions, a gain or loss of mass was observed, and this did not fit the model. The combustion of organic compounds, for example, produces residues whose mass is less than that of the burned substance — as in the case of a candle. The decrease in mass was attributed to the release of phlogiston. However, in the calcination of metals, the phenomenon was the opposite: the mass of the formed calx (the metallic oxide) is greater than the mass of the original metal. In the burning of metallic magnesium, for example, the resulting oxide has a mass greater than that of the magnesium initially present. This mass gain could not be explained by the phlogiston theory, revealing a fundamental inconsistency that would later pave the way for Lavoisier's interpretations (MAAR, 1999).

How to explain the anomalous observation, according to Thomas Kuhn's designation (1991), in which the residues gain mass during the reaction, instead of losing it? This contradiction was an anomaly for the dominant paradigm of the time. It is worth noting that the phlogiston paradigm survived for about 100 years, even after the Oxygen Theory. Here we raise a question that interests us to discuss in this article, namely, even trained scientists and followers of a methodical reasoning remained for a century with the belief in the existence of a principle of fire – phlogiston – what can be expected from lay people, without training, driven by beliefs and transcendental explanations? This is the problem that afflicts us today, in contemporary times, with denialism on the rise due to the daily emotional bombardment of disinformation, Fake

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News, and conspiracy theories. This issue will be discussed in another section of this text.

Continuing with episode 2, we will describe the clash between scientists in the face of the results and arguments produced on the same subject throughout history.

To explain the increase in mass of the calcination products, it was argued that phlogiston, as a principle of lightness, could, on certain occasions, escape into the ether, leaving the body heavier, i.e., the oxide - the product of calcination. Data and observations from metallurgy favored the belief in phlogiston as an explanatory principle. How? By adding charcoal (rich in phlogiston) to the metal oxide, pure metal was obtained. Following this logic, according to the principle of phlogiston, Magnesium Oxide, taken as an example, when heated in the presence of charcoal, would absorb phlogiston and thus transform into pure metal (see calcination reactions and metallurgical application in Scheme 1 and 2). It is important to compare the reactions conceived by Stahl with those demonstrated by Lavoisier, maintained and accepted today, based on the Oxygen Theory.

Table 3
Calcination

Sthal	Heat Metal → Calx + Phlogiston (decomposition)
Modern Understanding	Metal + Oxygen → Metal oxide 2 Mg(s) + O_2(g) → 2 MgO(s) (addition)

Source: Authors, based on Maar (1999), with slight modifications.

Table 4
Metallurgy / Steelmaking

Stahl	Calx (oxide) + Charcoal (phlogiston) → Metal
Modern Understanding	Metal oxide + Carbon → Metal + Carbon dioxide 2 Fe_2O_3(s) + 3 C(s) → 4 Fe(s) + 3 CO_2(g)

Source: Authors, based on Maar (1999), with slight modifications.

Thus, according to the idea of the phlogistic principle, which dominated chemical thought for almost the entire 18th century, "calcining would be like killing the metal which, thus mortified, would be heavier."

For Maar (1999), "understanding the nature of phlogiston and the explanation of the phenomena it intends to interpret is one of the most difficult aspects of pre-

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Lavoisier Chemistry, and depends more on the reader's understanding than on an exposition by the author" (MAAR, 1999 p. 476).

To understand the paradigmatic change carried out by Lavoisier, it is important to emphasize the inversion between addition and decomposition reactions. In combustion and calcination, a reaction with oxygen occurs, which was not conceived by Stahl, since in his conception this reaction would simply be a loss or gain of phlogiston. He thought that in calcination, the metal lost phlogiston (decomposition, metal – phlogiston) but, as we know today, it is an addition (oxygen + metal).

In metallurgy, according to the phlogiston paradigm, the metal oxide (which was called calx) gains phlogiston, which would be an addition. However, this reaction is understood today as a decomposition that can be explained as follows: mercury oxide (metal + oxygen), when heated, releases oxygen and leaves pure metal - a decomposition reaction. The inverted and mistaken understanding, which dominated chemical thought for almost a century, would have to wait for Lavoisier for the mechanism of calcination / combustion to be completely understood, thus enabling the advances that followed and which founded the emergence of modern chemistry.

A tool of analysis, used here to understand the history of science, is dialectics (Silva; Arcanjo, 2021), understood as a rational process in which contradictions are not considered logical paradoxes but the driving force of thought. This force is dynamic and creative because it proceeds through the overcoming of contradictions by provisional syntheses. That is, the overcoming achieved with the synthesis can proceed in a dialectical movement to the extent that it, the synthesis, already carries within it the embryo of a new thesis and its contrary, the antithesis, i.e., a contradiction. The driving force, used here as a metaphor for creative spiral movement, is fueled by the struggle of contraries (Cury, 1989; Chauí, 2003).

In the specific case of the passage from alchemy to modern chemistry, we could start from the dominant Aristotelian thought for millennia, which conceived fire as a constitutive element of matter — the thesis. The alchemists, in turn, proposed a distinct view: fire would not be an element, but the release of a principle – phlogiston - inherent to certain bodies - the antithesis.

Although laden with flaws, inversions, and errors, the antithesis represented a momentary and crucial advance for research in that historical period. By denying the conception of element (thesis) it stimulated chemical research and allowed numerous discoveries, gaining notable adherents such as Cavendish (1731–1810), Scheele (1742–1786), and Priestley (1733–1804), among others. As Bachelard teaches us (1985),

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scientific knowledge is dialectical by nature. Thus, not by chance but as a consequence of the dialectical movement itself, it was precisely the research of these same scientists — initially defenders of phlogiston - that produced the empirical data later used by Lavoisier to build a synthesis that overcame the prevailing contradiction of that time. What then was this synthesis?

When oxygen was identified as the agent of combustion, fire ceased to be understood as an element (Aristotelian thought) or as a principle, of fire or lightness (alchemist thought) and came to be understood as a chemical reaction that obeyed the law of conservation of mass. This new conception – the synthesis – would explain not only combustion but many other related processes such as fermentation, respiration, calcination, among others.

Thus, schematically:

- Thesis: Fire is a constitutive element of the world;

- Antithesis: Fire is not a constitutive element, but the release of a principle - phlogiston;

- Synthesis: Fire is neither an element nor phlogiston, but a chemical oxidation reaction.

It should be noted that the antithesis – phlogiston - was not a mere negation, but a refined negation, as it expressed an explanatory principle for the phenomenon in substitution of what, in the thesis (element), presented itself as a constitutive element. The synthesis, in turn, went beyond a simple correction since it elevated understanding to a new level – a complete explanation, that is, the proposition of a generative mechanism that, once in action, produces the phenomenon itself — fire (Maturana, 1967; 2001).

Although it is not our objective to deepen the conceptions about fire but rather to use its scientific, historical, and epistemological study to reflect on disinformation and Fake News, it is appropriate to conclude this topic by noting that Lavoisier's purely chemical view proves insufficient today to explain flame propagation. This is the beauty of dialectics, for which every synthesis already carries within it the embryo of a new thesis and, from it, by logical consequence, new contradictions.

Today, fire is understood as a complex physico-chemical process: a chain oxidation reaction, highly exothermic, occurring in the gas phase and sustained by the continuous production of free radicals and heat transfer. While Lavoisier saw fire as a reaction on the surface of materials, the flame is now understood as a heated gaseous medium that can present characteristics of plasma — the fourth state of matter —

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since, at sufficiently high temperatures, the gas partially ionizes, forming positive ions and free electrons. Although not all flames reach a sufficient degree of ionization to be classified as plasma in the strict sense of the concept, this interpretation helps to highlight the involved physico-chemical complexity. Thus, the modern understanding of fire and heat rests on three essential physico-chemical pillars: (a) Kinetic Molecular Theory, which explains heat as energy associated with particle movement; (b) Chain Reaction, mediated by free radicals, fundamental for sustaining the flame and (c) Thermochemistry, which describes the energy released or absorbed in chemical transformations. The engine of the process is pyrolysis — the heat-induced breakdown of molecules — which generates free radicals, extremely reactive species due to the presence of unpaired electrons. These radicals attack other molecules, breaking them and generating new radicals. The process becomes self-sustaining when the energy required to break chemical bonds is less than the energy released in the formation of new bonds. It is the released heat that keeps the flame alive; without this chain reaction, the fire would quickly extinguish.

Thus, the new dialectical triad of fire can be updated with the following scheme:

- Thesis (Lavoisier, 18th century): fire is a chemical oxidation reaction.

- Antithesis (19th–20th centuries): fire is not only a chemical reaction, but a physico-chemical phenomenon.

- Synthesis (modern view): fire is a dynamic system out of equilibrium - a self-sustained exothermic oxidation process occurring in the gas phase (or with plasma characteristics), mediated by free radicals in a chain reaction.

If the use of dialectics can help us understand the history of science, could we use this history and dialectics itself, with its triads - theses, antitheses, and syntheses - to problematize disinformation, denialism, and fake news in the context of formal education and also of science popularization?

Science Education

In 2024, CNN reported that Canadian student Brenden Sener, 13, was awarded at a science fair for building a miniature version of the device attributed to Archimedes, receiving a gold medal and an award from the London Public Library for his feat (Nicioli, 2024). It is not our interest to resume the discussion of the "burning mirrors," even though this historical fact sparks interest in textbooks, physics courses, and school experiments. We are interested, however, in discussing how school and pedagogical

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practices and science popularization can contribute to combating structural denialism and disinformation.

In this sense, the name of Educator Paulo Freire must always be remembered. From his extensive work and legacy (Freire, 1969; 1970; 2002), we learn that education is a dialogical and dialectical process between educator-students and student-educators through problematizations about the world. In this critical and creative process, it is possible to become more "conscious" of our circumstance – the society in which we live. However, for this conscientization to occur, it is necessary for student-educators and educator-students to learn to read the world and understand its context and history. Thus, for Paulo Freire (1969; 1970), education should be understood as a process that leads the individual to recognize themselves as an agent who lives in the world but also creates the world with their actions. This double recognition is reached through the movement of internal contradictions between reason and the material world and the material conditions of the world in which reason exists (Andrade; Silva, 2021). According to this Freirean conception, the act of reading cannot be dissociated from reading the world, and it is not just about reading and knowing the things of the world, but effectively transforming it – which inscribes education as a practice of freedom.

Freire (2002) was dialectical in his relationship with the world but also with the students who had the privilege of living with him. Thus he said, in his dialectical orality:

> To educate is the task of those who know that they know little – and thus know that they know something and can thus come to know more – in dialogue with those who, almost always, think they know nothing, so that these, transforming their thinking that they know nothing into knowing that they know little, can equally know more" (Freire, 2002, p. 25).

Having said that, we ask ourselves: can we plan and implement dialectical classes and, more than that, cultivate dialectics in the educational sphere? This exercise must be thought out, elaborated, and practiced by every educator, given the specificities of the disciplines. In a general way, some characteristics are common, namely: it is important to facilitate the development of systemic thinking, i.e., value interconnections instead of simple causes, stimulate debate in the classroom through the presentation of academic seminars but also through playful practices such as films and theatrical sketches (Boal, 2013) about the history of science. These playful practices

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facilitate the recognition that scientific knowledge is provisional and that science does not produce unquestionable truths, but good propositions that can be refuted in the face of new evidence.

On the part of the educator, it is expected that they value questions, show how science is built, as in the cases reported here, and foster respectful debates with students, since the use of dialectics in education is not about winning with arguments, but about building richer and more complex understandings through the confrontation of ideas.

In the educational context, dialectics can be powerful in combating disinformation because it attacks not only specific lies but also the structure of thought that makes them easily acceptable. Thus, for example, in the thesis that vaccines cause autism, one should stimulate debates, encourage the creation of antitheses, and even show students that there is no causal relationship between the two phenomena: vaccination and autism. In this context, some questions cannot fail to be formulated, namely: What interests may be behind a certain narrative? What evidence supports one or another statement? What complementary information is missing? What antitheses can be formulated? Is it possible to formulate a synthesis?

Even though a dialectical exercise can be done to teach any academic discipline, science education is a privileged educational space for such an exercise and, therefore, should be encouraged and supported, including with its experimental arm. In this perspective, recent institutional initiatives reinforce the centrality of this approach. In 2024, the Ministry of Education (MEC), in partnership with MCTI and CNPq, launched the *Programa Mais Ciência na Escola*, whose objective is to promote digital literacy and scientific education through the implementation of maker laboratories in public schools, accompanied by teacher training, activity plans, and scholarships for teachers and students. By encouraging experimental practices, investigative projects, and new approaches, the program aligns with the scientific competencies foreseen in the BNCC and the guidelines of the National Digital Education Policy (PNED), in addition to directly dialoguing with the expansion of school time through the Full-Time School Program. Thus, structuring actions by MEC, with the support of MCTI, show that experimentation, creativity, and investigation continue to be fundamental dimensions for strengthening Science Education in Brazilian basic schools and, perhaps, for the future of science in Brazil.

Science Popularization

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Science popularization, when implemented from a dialectical perspective, is not reduced to the mere vertical transmission of information from a center of knowledge, universities, to a lay public. It configures itself as a dynamic process of unveiling in which scientific knowledge ceases to be an end in itself, a hermetic and alienated knowledge, to become a tool for criticizing and understanding the world.

By explicating the methods, conflicts, uncertainties, and social applications of science, this process demystifies the aura of neutrality and absolute truth in which it is often conceived, both by laypeople and by part of academia itself, thus revealing its imbrications with material interests and power structures. It is precisely in this demystification that its emancipatory potential resides: by making the instruments of critical-rational thought accessible, science popularization empowers citizens to decipher reality more incisively and autonomously, questioning naturalized determinations and, even, consciously participating in democratic struggles and the affirmation of national sovereignty.

Within the scope of our discussion, we would say in the fight against denialism and professional disinformation, carried out by reactionary groups. In this way, far from being an act of "donation" of knowledge or salvationism (Freire, 2002), science popularization is realized as a praxis that, by appropriating knowledge that was previously foreign to the lay population, contributes to the formation of historical subjects conscious of their capacity to transform their own reality. In a recent article, Silva and collaborators (2025) problematized the use of some terminologies used in the practice of socializing scientific knowledge and stated that the fundamental question of the problem is not one of nomenclature or language - communication, diffusion, literacy, or scientific literacy - but with whom this practice "sides within the struggles that history imposes, i.e., being able to answer the question: scientific dissemination for whom do I want you?"

Final Considerations

The lessons drawn from Archimedes and Lavoisier transcend the scope of the history of science and offer a powerful analytical framework for facing the epidemic of disinformation in contemporary times. The two historical episodes function as metaphors for the challenges we face today.

The case of Archimedes and the burning mirrors illustrates a phenomenon we can call a resilient narrative. Even though its factual veracity has been disputed for centuries, the power of this story lies in its ability to encapsulate a conceptual truth –

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Archimedes' innovative genius – and to remain alive as a pedagogical and cultural instrument. Similarly, modern fake news and conspiracy theories are rarely created from nothing. They generally rely on fragments of truth, real fears, or legitimate distrusts, the shadow of the Roman ship, which are then distorted and amplified through spectacular and emotionally charged narratives - the miraculous fire. The central question ceases to be the truth and becomes why this story resonates and propagates, regardless of its verification?

The transition from phlogiston to the Oxygen Theory offers a model for understanding the dynamics of scientific denialism. The phlogiston theory was not simple nonsense; it was a coherent paradigm that explained many observations and was defended by brilliant minds. Its resistance to change, even in the face of anomalies like the weight gain in calcination, demonstrates how a belief system can be maintained and endure for a long time through *ad hoc* adjustments, i.e., sometimes phlogiston escapes, at other times phlogiston incorporates into matter – just as we see in current conspiracy theories, which adapt to incorporate any contrary evidence as a supposedly predictable part of the nearly discovered plot. The overthrow of phlogiston required more than new results, but, above all, a complete conceptual restructuring, a new way of seeing the chemical world.

It is precisely this conceptual restructuring – the willingness to traverse other paths of knowledge to find new, revealing conceptual landscapes – that disinformation seeks to sabotage. In this perspective, the confrontation occurs when conspiratorial theories and instrumental denialism are replaced by the dialectical process, with its nuances, contradictions, and self-correction. A replacement of certainties, usually simplistic, dogmatic, and immutable, by an instituting process of producing syntheses that overcome contradictions. Thus, while disinformation thrives on the stagnation of thought, the denial of the contradictory, and the delegitimization of sources of epistemic authority, critical education and engaged science popularization build emancipatory and democratic paths of social inclusion and affirmation of national sovereignty.

Therefore, the most potent antidote against disinformation is not simply an automatic and infinite self-correction, but the active promotion of what we can call here dialectical literacy. This means educating new generations not only about what we know, but about how we know it; about the long, tortuous, and often counterintuitive paths that humanity has traveled to build this knowledge. Teaching about Archimedes' mirrors and Stahl's phlogiston is, ultimately, teaching intellectual humility, healthy

skepticism, and the courage to abandon simplistic and comfortable ideas in favor of denser and more robust explanations. It is necessary to educate the youth and also the general public with the same tool that allowed Lavoisier to see oxygen where others only saw the absence of phlogiston: the ability to think critically, historically, and systemically.

In this sense, to combat disinformation, it is necessary to invest in programs such as "Mais Ciência na Escola" and "Lugar de ciência é na Escola" and, in the broader social field, to work with the socialization of knowledge from an emancipatory and inclusive perspective.

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RESUMO

Este artigo tem como objetivo analisar o fenômeno contemporâneo da desinformação e das *fake news* a partir de lições extraídas da história da ciência, especificamente dos episódios dos "espelhos ardentes" de Arquimedes e da passagem da alquimia para a química moderna, com o trabalho liderado por Lavoisier. A metodologia consiste em uma análise histórica e epistemológica, utilizando a dialética como ferramenta para compreender a superação de paradigmas. O estudo do caso dos espelhos ardentes revela como narrativas podem perdurar independentemente de sua veracidade factual, funcionando como metáfora para as *fake news* que se alimentam de fragmentos de verdade. Já a análise da transição da alquimia para a química moderna demonstra como sistemas de crenças coesos podem resistir a anomalias por longos períodos, à semelhança do negacionismo científico atual. Conclui-se que o combate à desinformação não reside na mera correção de fatos, mas na promoção de uma educação crítica e de uma popularização da ciência comprometida "para quem te quero". Com ambas enfatizando o processo dialético de construção do conhecimento – suas incertezas, contradições e capacidade de autocorreção. Dessa forma, defende-se que iniciativas como o "Programa Mais Ciência na Escola" e uma popularização da ciência comprometida com as causas populares, são fundamentais para formar uma sociedade capaz de pensar de forma histórica, sistêmica e crítica.

PALAVRAS-CHAVE: Desinformação. Fake News. História da Ciência. Epistemologia. Ensino de Ciências e popularização da ciência.

RESUMEN

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Este artículo tiene como objetivo analizar el fenómeno contemporáneo de la desinformación y las noticias falsas a partir de lecciones extraídas de la historia de la ciencia, específicamente de los episodios de los "espejos ardientes" de Arquímedes y el tránsito de la alquimia a la química moderna, con el trabajo liderado por Lavoisier. La metodología consiste en un análisis histórico y epistemológico, utilizando la dialéctica como herramienta para comprender la superación de paradigmas. El estudio del caso de los espejos ardientes revela cómo las narrativas pueden perdurar independientemente de su veracidad factual, funcionando como metáfora de las noticias falsas que se alimentan de fragmentos de verdad. Por su parte, el análisis de la transición de la alquimia a la química moderna demuestra cómo los sistemas de creencias cohesivos pueden resistir a las anomalías durante largos períodos, de manera similar al negacionismo científico actual. Se concluye que el combate a la desinformación no reside en la mera corrección de hechos, sino en la promoción de una educación crítica y de una popularización de la ciencia comprometida "para quien te quiero". Ambas deben enfatizar el proceso dialéctico de construcción del conocimiento: sus incertidumbres, contradicciones y capacidad de autocorrección. De esta forma, se defiende que iniciativas como el "Programa Mais Ciência na Escola" y una popularización de la ciencia comprometida con las causas populares son fundamentales para formar una sociedad capaz de pensar de forma histórica, sistémica y crítica.

PALABRAS CLAVE: Desinformación. Noticias Falsas. Historia de la Ciencia. Epistemología. Enseñanza de las Ciencias y Popularización de la Ciencia.