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The Photon is Naked: The Role of Textbook in the Building of a Common World

O Fóton Está Nu: O Papel dos Livros Didáticos na Construção do Mundo Comum

El Fotón Está Desnudo: El Papel del Libro de Texto en la Construcción de un Mundo Común

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Abstract

Given the ontological plurality associated with Quantum Theory (i.e., the multiplicity of interpretations of the theory), we investigated the approaches of 22 undergraduate textbooks in the process of composing a possible common world about electromagnetic radiation. In the work, we align ourselves, on the one hand, with the proposals of Eduardo Viveiros de Castro, Bruno Latour and Isabelle Stengers, arguing that reality occurs through a cosmopolitical process in which non-transcendental multinatures negotiate to achieve common stabilization. These perspectives collide with a central metaphysics of modernism: a reality grounded in a unique and innate nature (called cosmopolitan). On the other hand, we started from Bakhtin's Philosophy of Language to analyze the style of speech cited in the books. The main analysis of the text is to identify whether the books are cosmopolitan or cosmopolitical, and whether the boundaries of the cited discourse are explicit or erased. The results found in our analysis indicate that there is no ontologically stabilized electromagnetic radiation proposition when we consider all textbooks. However, as most of these same books hide the limits between propositions, it is evident that the authors simulate that there is a consensus in the scientific community regarding their ontology.

Keywords: Quantum Physics, textbooks, discourse analysis

Resumo

Dada a pluralidade ontológica associada à Teoria Quântica (isto é, a multiplicidade de interpretações da teoria), investigamos as abordagens de 22 livros didáticos de graduação no processo de composição de um possível mundo comum sobre radiação eletromagnética. No trabalho, alinhamo-nos, por um lado, às propostas de Eduardo Viveiros de Castro, Bruno Latour e Isabelle Stengers, defendendo que a realidade se dá por um processo cosmopolítico em que multinaturezas não transcendentais negociam para alcançar uma estabilização comum. Essas perspectivas colidem com uma metafísica central do modernismo: uma realidade fundamentada em uma natureza única e inata (chamada de cosmopolita). Por outro lado, partimos da Filosofia da Linguagem de Bakhtin para analisar o estilo de discurso citado dos livros. A análise principal do texto se dá no sentido de identificar se os livros são cosmopolitas ou cosmopolíticos, e se as fronteiras do discurso citado estão explícitas ou apagadas. Os resultados encontrados em nossa análise indicam que não há uma proposição de radiação eletromagnética estabilizada ontologicamente, quando consideramos todos os livros didáticos. No entanto, como a maioria desses mesmos livros esconde os limites entre as proposições, é evidente que os autores simulam que há um consenso na comunidade científica a respeito de sua ontologia.

Palavras-chave: Física Quântica, livros didáticos, análise de discurso

Resumen

Dada la pluralidad ontológica asociada con la teoría cuántica (es decir, la multiplicidad de interpretaciones de la teoría), investigamos los enfoques de 22 libros de texto universitarios en el proceso de componer un posible mundo común sobre la radiación electromagnética. En el trabajo nos alineamos, por un lado, con las propuestas de Eduardo Viveiros de Castro, Bruno Latour e Isabelle Stengers, argumentando que la realidad se da a través de un proceso cosmopolítico en el que multinacionales no trascendentales negocian para lograr una estabilización común. Estas perspectivas chocan con una metafísica central del modernismo: una realidad basada en una naturaleza única e innata (llamada cosmopolita). Por otro lado, partimos de la Filosofía del lenguaje de Bajtín para analizar el estilo de habla citado en los libros. El principal análisis del texto es identificar si los libros son cosmopolitas o cosmopolíticos, y si los límites del discurso citado son explícitos o borrados. Los resultados encontrados en nuestro análisis indican que no existe una propuesta de radiación electromagnética ontológicamente estabilizada cuando consideramos todos los libros de texto. Sin embargo, como la mayoría de estos mismos libros ocultan los límites entre proposiciones, es evidente que los autores simulan que existe un consenso en la comunidad científica respecto a su ontología.

Palabras clave: Física Cuántica, libros de texto, análisis del discurso

Introduction

The development of the Quantum Theory (QT) formalism was established at the beginning of the 20th century and lasts until today. On the other hand, since its formulation, different ontologies have been proposed, as in the case of wave-particle duality problem, in which wave, corpuscular and dualist views compete with each other, without any of them having manage to stabilize ontologically (Jammer, 1974). Several programs of research are dedicated to the study of these ontologies (Freire Jr et al., 2011), also their insertion in the formal education (Montenegro & Pessoa Jr., 2002) and the way they are presented in textbook (Pereira et al., 2019; Vazata et al., 2020).

Despite the ontological plurality around the QT, research in scientific education shows that Physics textbooks, either in highschool or college level, usually don't approach this discussion. Conceptual and philosophical issues are suppressed in favor of a instrumentalist presentation, disregarding the contention about the theory (Freire Jr et al., 2011) and, therefore, assimilating positivist and absolutist views of science.

Since the release of *The Structure of Scientific Revolutions* by Thomas Kuhn (1996), in which the author defends that the actual paradigm is presented to scientists through textbooks, the scientific education has been dedicated to deeply understand the structure of these manuals and its implications for science and society (Badino & Navarro, 2013; Olesko, 2006; Yamazaki et al., 2017). A wide discussion on the research about textbook as a cultural tool in Science and Science Education is found in (Simon, 2016). Many researches point to conceptual and epistemological contradiction in textbooks (Chaib & Assis, 2007; Langhi & Nardi, 2007b; Lima et al., 2017). Many others already to discuss the pedagogic-political aspects of textbooks: Vilanova (2014) analyzes the conception of citizenship in textbooks, Martins (2006) outines the main researchers on textbooks

under speech analysis methodologies, Vazata et al. (2020), besides, propose that textbook is one of the ways in which science is represented before society, doing part of the social imaginary formation about what science is.

Due to this context, we can question ourselves about how this instrumentalist way of introducing QT in textbooks impacts scientific education and society. It is widely known that diverse lines of research in scientific education criticize positive and modernist views of science. Sociocultural perspectives understand science, for example, as a human sociocultural activity (Lemke, 2001) that cannot be disassociated from the social context of specific time and place. In this sense, the Science, Technology and Society movement questions the neutrality and scientific salvationism (Auler & Delizoicov, 2001; Santos & Mortimer, 2002), seeking to promote an educational research propose aligned a non-neutral and non-absolutist conception of science that focus the social well-being (Bencze et al., 2020; Hodson, 2003; Yacoubian & Hansson, 2020) laws, theories, innovations.

These perspectives, otherwise, don't collide with a central metaphysics of modernism: a grounded reality in a single and innate nature. According to Latour (2004) and Stengers (2007) the modernist conceptions about science come from that reality is taken through a cosmopolitan process: a single transcendental nature that serves as the basis for access to true knowledge, to which science has privileged access. In order to don't fall into an ethnorist cosmoview, Eduardo Viveiros de Castro (1996), based on Amerindian perspectives, defends the need to consider that humans and non-humans share the world in distinctive ways, and, thus, exist in different natures, namely, multinatures.

Dialoguing with this conception of Eduardo Viveiros de Castro, Latour and Stengers propose that reality is given by a cosmopolitical process (and not a cosmopolitan one): non-transcendental multinatures that trades to achieve a common world stabilization.

Aligned to this view, we acknowledge that the propositions of Einstein, Schrodinger, and others, about the duality of wave-particle problem, aren't propositions about a single nature, but different natures, dealing with different beings of the world negotiating for the stabilization of a common world. Our proposal is, therefore, to analyze the ontological trajectory of the different natures of light in undergraduate textbooks, to understand how these natures are approached in the books.

We defend that there are political and pedagogical commitments linked to cosmopolitan or cosmopolitical approaches in undergraduate textbooks. In this perspective, books that hide the debate around the ontological plurality of electromagnetic radiation were cataloged as cosmopolitan; while those that expose were cataloged as cosmopolitics.

Given this context, our questions of research are the following:

1° What is the approach of textbooks of Quantum Mechanics in the composition process of a possible common world: cosmopolitan or cosmopolitical?

2° Which are the discursive resources used by the authors in each of these approaches?

3° How is it given the ontological trajectory of the presented propositions in these textbooks?

4° Besides, based on these discussions, we propose a reflection around this issue: Which are the political and pedagogical commitments of a cosmopolitan or cosmopolitical approach in textbooks?

The End of Peace Agreement of Nature and the Common World Composition

The philosophical principles of modern science caused great impact in contemporaneous culture formation, mainly in the western world. A lot of researchers dedicated themselves to understand, by different perspectives, the roots of this belief and its influence on social structure (Bachelard, 1938; Shiva, 1993; Stengers, 1993; Whitehead, 1925). According to Latour (1993), what marks the birth of modernity is the assumption that we can quell social and discursive dimensions from scientific data through a purification process. Latour points out that this purification belief is impracticable, due to scientific data only can be obtained and interpreted through scientists. This belief furthermore establishes the conception that scientific knowledge is absolute and universal.

Since the late 19th century, on the other hand, a lot of philosophical movements have put in suspicion these foundational conceptions of scientific culture. After the second world war, one of these movements, the science studies, was dedicated to the relationship between science and society (Collins & Evans, 2002). Some of the authors of this movement promoted what was called the "ontological turn" (Latour, 2017a; Stengers, 1996), which was against modernist ontological rupture between nature and society, as well as maintained that there is neither a truth nor a single reality (Lima & Nascimento, 2022), a perspective also found in Amerindian cosmologies (Castro, 1996).

As a critic of modern society, Latour (1999) understands that reality should be seen as a gradient and not as two poles (existence and nonexistence), in other words, we can have an enlarged or a constrict reality. The philosopher dedicated himself to study science from his anthropology of laboratory, analyzing the process of stabilization of scientific facts (Latour & Woolgar, 1986). A scientific fact, according to Latour, is a non-human who requires being articulated by a scientist (human) to another humans (scientists, politicians, teachers, journalists, businessmen) and others non-humans (another facts, textbooks, academic articles, lab tests) building, this way, networks. The job of a scientist is, therefore, stabilize actants[1] through articulation and expansion of its networks, in order to make them autonomous. Thus, a network, even being small and simply articulated, means a reality. Different collectives, about the same topic, may coexist. Nonetheless, these collectives have a reality hierarchy, which can be observed from the network's size and its articulation quality.

1 Latour takes this term from semiotics to refer not only to human actors, but also non-human ones. Scientists, the wave function, educators and textbooks are, for example, actants.

According to Latour (2004a), the usual political view, on the other hand, comes from the principle that all humans use as base one only nature (one only reality), inert and usual given by the European occidental world and acting as guiding principle of peace accords. Hence, war and conflicts are consequences from different visions of a given reality, so, to reach peace, it is just needed reconciliation between humans that diverge only in cultural fields. Inside this conception, there are multicultures about transcendental and inert mono nature. This vision, defended, for example, by the sociologist Ulrich Beck, (Latour, 2004b) refers to the kantian version of conflicts resolution, named **cosmopolitan**: there is only one cosmos, to which we can have different interpretations about what it is, as transcendent e independent from the observer (Blaser, 2016).

For Latour (2004b) and Stengers (2007), in another way, dealing with conflicts is something more complex, because, as it was said before, there is no comfort of a transcendental mono nature that can be used as reference. This modernist way of conflict resolution makes democracy impossible, since there's a transcendental nature in which access is obtained only by scientists and just need one specialist who finds answers in the cosmos to put them in practice. In the author's conception, there're natures that compete through actants' articulation to stabilize a possible common world to all from a cosmopolitan process. This process never ends and never reaches full stabilization, since that humans and also non-humans aren't inert and have agency, actively participating on networks. So, the articulations aren't inert in the cosmopolitical process. Stengers defends that resolution of conflicts occurs, therefore, from a **cosmopolitical** process: there are multi cosmos, different cultures can see different cosmos, consequently, it isn't transcendent, depending on the observer (Stengers, 2007).

According to Latour, cosmopolitics must be oriented to find a common reality to all, a singularity. In this way, cosmopolitics serves to try to articulate a common world, so the conflicts can be solved. On the other hand, under no circumstances, a common world, previously established by one culture, should be used as a starting point. Stengers, in turn, understand that construction of a singularity can let invisible historical groups out (women, black people, amerindians and aboriginals, for example), making up a common world very close from transcendent cosmos from cosmopolitan proposal. Since that, Stengers asks for a braking of common world construction[2].

Front War of Physics: Waves x Particles

There is a front war in the scientific field. That is, as from an established world conception, the search for the "truth" about nature of different actants. The dispute related to the light nature is configured as one of the most blooded; a battle in an open field between corpuscular, undulatory and dualist ontologies. Unlike other fields of scientific research, there is no composition of a common world in quantum physics. Different propositions of electromagnetic radiation (ER) compete through a cosmopolitical process, due to establish themselves as a fixed proposition.

2 An example of conflict between multinatures can be found in the article (Blaser, 2016). The author is based on the cosmopolitical proposal of Stengers and Latour in order to resolve a conflict between local authorities, from a city in Canada, and indigenous communities regarding reindeer hunting.

The light ontology has been the focus of discussion for centuries. Many physicists such as Newton and Huygens explored the subject from different optics, looking to understand its shapes and characteristics. One of the most polemic points of the discussion that lasts until today is about corpuscular and undulatory nature. Along the 19th century, however, this discussion was discouraged, because of the stabilization of undulatory ontology of light. A lot of phenomena related to diffraction and interference of ER problems had been already studied by Fresnel, Young, others, and the undulatory conception of light responded exceptionally well to them. Also, in 1861, James Maxwell structured the union of Magnetism and Electricity Laws, creating the electromagnetic theory, which describes light as the result of magnetic and electric field combination traveling as a wave in a continuous field. Such theoretical presumptions were still corroborated by Heinrich Hertz experiments in 1886.

At this moment, the sociotechnical network of undulatory ER of continuous fields had a series of human actants (Maxwell, Young, Hertz), as well as non humans actants (electromagnetic theory, explanation of undulatory phenomena of interference), which articulated to ontologically establish themselves. In addition, electromagnetism, thermodynamics and mechanics were set as pillars of what we know as Classic Physics (Lima et al., 2020).

Nonetheless, in the end of the 19th century there was a phenomenon that couldn't be explained through existing theories. In 1860, Gustav Kirchhof proposed an idealized body, named dark body (which absorbs all incident radiation and later emits it). The emission spectrum of radiation of the dark body couldn't be explained from classic electromagnetism and thermodynamics. There were the Wien and Rayleigh models, which described, each one, part of the emission spectrum. However, only Planck, since the interpolation of both theories, proposed a radiation equation of the dark body that covers all the spectrum. In his attempt to explain the spectrum, Planck suggested that the dark body atoms emit radiation as a harmonic oscillator in a discrete set of frequencies. Planck, thus, suggests that the emission of radiation energy of the dark body is quantified.

The quantification of Planck had as consequence a ontological destabilization process of the light as wave along the first half of 20th century, since that caused great revision of physical theories (Jammer, 1966); one more time the light nature was put in check. Besides the shocks between corpuscular and undulatory conceptions, there were also disputes between realistic and idealistic conceptions of ER. In this scenery, realism is associated with the conception that there's a reality "out there" that doesn't depend on an observer, as in the case of Schrodinger waves. Otherwise, the idealism is associated with a conception that human conscience has crucial appeal in the ents description, as in the case of Bohr complementarity[3].

3 These definitions of realism and idealism are simplified descriptions and intended for a better understanding of the philosophical positions associated with the different propositions of ER, presented in this article. Within philosophy there are several conceptions of realism and idealism, a better description of these philosophical positions can be appreciated in the book (Pessoa Jr., 2003), related to the context of Quantum Mechanics and in

In this context, many physicians of the time wished for a description of ER nature. (Lima et al., 2020) studied original articles of Einstein, De Broglie, Schrodinger, Born and Bohr, to identify how these authors conceived light nature. With the same purpose, we study original articles of these authors, including the ontological conception of Max Planck, creating our own categorization. From this taxonomy, we investigate in graduation textbook which of them were present. As shown below, we described the principal characteristics of these prepositions, bringing direct quotes of seminal articles. This catalog was inspired by the book *Conceitos de Física Quântica* (Pessoa Jr., 2003).

Proposition 1 — Classic Undulatory — Planck (1901): the author doesn't have a quantified vision of ER. In the Planck conception, radiation interacts with matter, which has oscillators with quantified energy, as illustrated: "It is evident that now the distribution of P elements of energy between N resonators only can occur by a finite number and determined manner." (Planck, 2000, p. 539). The light propagates as a classic electromagnetic wave. So, his vision is **undulatory** and **realistic**.

Proposition 2 — Corpuscular — Einstein (1905): this is the first proposition that intends an undulatory vision review of electromagnetic radiation. For Einstein, the light "... consists of a finite number of energy quanta that are localized in points in space, move without dividing, and can be absorbed or generated only as a whole." (Einstein, 1987, p. 87). So, his vision is **corpuscular** and **realistic**.

Proposition 3 — Dualistic realistic — De Broglie (1923, 1924): De Broglie presented his first proposition in 1922, adopting a realistic corpuscular perspective, but in the following years it has been modified. Its most remarkable characteristic is the notion of pilot wave. According to the author, "... any moving body may be accompanied by a wave and that it is impossible to disjoin motion of body and propagation of wave." (de Broglie, 1924, p. 450). As it is clear in another part of article, De Broglie looks for reintegrate the corpuscular vision with undulatory: "I shall in the present paper assume the real existence of light quanta, and try to see how it would be possible to reconcile with it the strong experimental evidence on which was based the wave theory." (de Broglie, 1924, p. 446). Other characteristics that emphasize the author's vision is that his proposition has as foundation relativity and his description of quanta as holder objects of mass. So, his vision is **dualistic**[4] and **realistic**.

Proposition 4 — Undulatory — Schrodinger (1926): it presents a proposition that is strict undulatory. Ideas as trajectory and particle are only abstractions of pure undulatory phenomena.

> "Admittedly, the individual path of a mass point loses its proper physical significance and becomes as fictitious as the individual isolated ray of light. The essence of the theory, the minimum principle, however, remains not only intact, but reveals its true and simple meaning only under the wave-like aspect, as already explained." (Schrodinger, 1933, p. 309).

the article (Pessoa Jr, 2009), in a more general context.

4 According to the authors, a system is considered dual "Only when a given physical system can be described both by a wave frame and a corpuscular frame on the same scale..." (Lima et al., 2020, p. 4, our translation). This definition was proposed by (Martins & Rosa, 2014).

In the beginning Schrodinger imagined that his proposal of wave function described a usual wave, but along his studies he realized that it was about a more complex wave (he talks about ψ as a waste-function in a configured space), since it represents continuous nature ents, it means: the light, mechanical processes and matter are wave. So, his proposal is **undulatory** and **realistic**.

Proposition 5 — Probabilistic — Born (1926): the author presents a probabilistic theory well-structured to describe quantum phenomenon. According to the author , is the probability of finding the particle between A and B, in other words:

> "...we should connect the undulatory equations with a picture like this: waves satisfying the equation don't represent the movement of matter particles in any way; they just determine possible movements, or even the state of matter. Matter can always be visualized constituting pontual mass (eletrons, protons)." (Born, 1926, p. 355, our translation)

His vision suspect, thus, the determinism of physics when proposing a reinterpretation of wave function ψ. It is not clear if his interpretation of Schrodinger wave function corresponds to a real ent (Lima et al., 2020). Because of it, his philosophical position is closer to an idealistic conception. So, his proposition is **probabilistic** and gets closer to a **corpuscular** and **idealistic** vision.

Proposition 6 — Dualistic Idealistic — Bohr (1928): known as the Complementarity Principle, Bohr proposes that with only one proposition it isn't possible to explain ER nature. His vision differs of other dual visions, because corpuscular and undulatory visions complement each other. Besides that, what defines adequate vision is the experimental apparatus, it means, only after measurement we can make conclusions about the ontology of the ent. The possibility of identifying the trajectory of the ent characterizes the corpuscle, while the interference pattern visualization denotes undulatory caracter. According to Bohr:

> "...evidence obtained under different experimental conditions cannot be comprehended within a single picture, but must be regarded as complementary in the sense that only the totality of the phenomena exhausts the possible information about the objects." (Bohr, 1995, p. 51, our translation)

Also according to the author "...complementary phenomena are shown in experimental arrangements mutually excludents..." (Bohr, 1995, p. 59, our translation). It is a wave (scheduled in the research program of Schrodinger), or it is a particle (scheduled in the research program of Heisenberg). So, his proposition is **dualistic** (wave or particle) and **idealistic**, since that only makes sense to determine what is light after the observator measures.

Proposition 7 — Hybridization: eventually the authors of textbooks mix the ontology of two or more propositions. Considering this, there is a new category, which reflects the own ontological conception of the works author about light.

The Role of Textbook to Forge the Common World and Ontological Trajectories of ER: A Discursive Analysis

The textbooks, as said before, are non-humans that compose the network of science actants doing the blood flux of science keeping up and running (Vazata et al., 2020). These works are reference for teachers of high school and college, in sense to present to society not only scientific theories but also the conception about "what science is" and which is its role. In this context, deeply analyzing and understanding the philosophical conceptions that permeate this document is of fundamental importance for us to forge a scientific education that proposes reflections on the relationships between sciences, social and environmental problems of the Anthropocene.

In the last sections we discussed how scientists willed to stabilize the actants networks, and how, according to cosmopolitan and cosmopolitical perspectives, the common world is forged. Besides all, we presented a discussion about a non-composition of a common world about ER ontology. Inside this scenery, we are interested in understanding how authors of quantum textbooks of higher graduation incorporate the propositions about electromagnetic radiation in Modern Physics context, how is this conflict approached.

In this context, understanding the composition process of the common world involves analysis of the actants' networks and the present discourse in these textbooks. Latour & Woolgar (1986), in *The Laboratory Life*, describe that ontological stabilization process of an actant, in scientific article, takes place through discursive transformation. For Latour an actant is a hybrid of something that is natural, social and discursive. Into this way, stabilizing one actante involves, also, stabilizing the discourse. Along the process of the discourse stabilization, statements with low degree of reality are gradually transformed into statements with high degree of reality. This stabilization process leaves discursive traces (Latour & Woolgar, 1986), and has already been a research focus in previous papers (Vazata et al., 2018, 2019, 2020). In the present article, as in the previous papers, we understand the analysis of Latour, who has only investigated scientific articles to study the ontological trajectory of actants in textbooks.

In the present research, intending to improve this discursive analysis, we propose an approach between science studies of Latour and the Bakhtin language studies. Both authors, Latour e Bakhtin, although focused in different fields of study, one willing languages and other science, they have intersections that allow theoretical approach with potential to enrich science textbooks analysis (Lima et al., 2018). Latour, as mentioned, understands that expanding an actant reality involves transforming the discourse. Bakhtin, on the other hand, understands that texts don't have an intrinsic reality, since, for him, a text doesn't finish in itself, but an extra verbal context, even from the author as the reader, composes its significance (Bakhtin, 2011).

In addition, besides the interaction between author and reader, a text also dialogs with other texts. The textbooks, for example, has determined discursive characteristics, which means that it is part of a specific type of discourse genre (Bakhtin, 1986b). When writing a physics textbook of higher education, the author will follow a certain style of

writing and structure of chapters to present the concepts, dialoguing with other books of the same genre. Still, it also requires dialog with seminal articles of scientists who proposed theories which are presented in the work (Lima et al., 2018). So, textbook is the result of dialog of different texts, added of surplus vision from the own author. Besides, as the text reading also incorporates the extra verbal context of the reader, the meanings in the book are potentially infinites (Bakhtin, 2017).

In this way, the textbook isn't a simple description of the original articles, but a interpolation between structure and style of discourse genre which it belongs, the original articles content and the surplus vision of the author's textbooks. We can investigate the structure of this dialog starting from the **mentioned discourse** analysis (Bakhtin, 1986a), because "The literary analysis of Bakhtin led him to conclude that the way how the discourse appears mentioned in the text (it means, the type of writing, involving the grammatical and phraseological choices) is closely linked with the author's world vision." (Lima et al., 2018, p. 346, our translation).

From the analysis of the mentioned discourse, thus, besides identify the actual different light natures in these textbooks, we can also verify how these propositions are presented by the authors, in the sense to understand which is the role of these books in the composition process of a common world. We understand that the books can fulfill two roles: **cosmopolitan books**, it means, books that assume that there is a predetermined nature to be descript occults the disputes between actants to stabilize being, this way, to service of a technocratic and authoritarian science; **cosmopolitical books**, it means, books that don't use as reference a transcendent nature to become explicit the disputes between actants to stabilize, putting themselves to service of a dialogical and democratic science.

Analytical Device for Analyzing the Role of the Textbook in the Composition of the Common World

To understand the role of science textbooks in the process of composing a possible common world, we created an analysis methodology based on the integration of the theoretical references discussed above. In our analysis, textbook are classified in four categories related a possible composition of the common world. The classification is synthesized in Fig. 1 below. Each category corresponds to a distinctive way of incorporating actants' natures. |In this work, our view is directed to ER analysis, however, this method can be used to analyze any actant that is not stabilized.

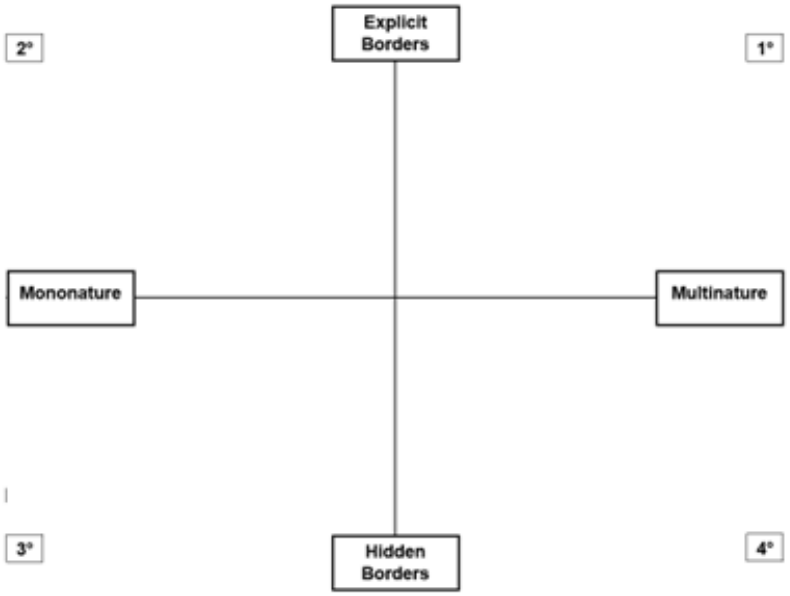
Firstly, we divide books in relation to nature's **quantity** found in the texts: on the left, are cataloged **mononature**'s works, it means, one only nature is presented or the author presents many, but defends only one; on the right, are cataloged the **multinature**'s works, it means, many natures are presented by the author and he doesn't defends non specific one. Secondly, we divide books in relation to the **way** these natures are presented by the author: below are cataloged works in which the author **hidden borders** between natures, it means, doesn't demonstrate that there's a possibility of exist other natures;

above are cataloged works in which the author **explicit borders** between natures, it means, he expose that there's a possibility of exist more than one nature. Thus, the first category of analysis came fro Latour's Science Studies (Latour, 2017b) while the second comes from Bakhtin's speech analysis (Bakhtin, 1986a).

After all, we succinctly describe the principal book's characteristics of each category:

Figure 1

Possibility of incorporating the different natures of an actant into textbooks



4º Quadrant: multinatures works are found in text and the author doesn't delimit explicit borders that distinct them. This book's category is *cosmopolitan*, because even it has different natures, begins from a pre-post one and doesn't present disputes between them to establish a winning proposition.

3° Quadrant: mononature works, whereas the author doesn't present any other possibility of nature besides the defended by him. Books from this category are also *cosmopolitan*, because they begin from the principle that there's only one nature and there isn't any presentation of any type of dispute between different propositions.

2° Quadrant: mononature works in which the author defends also a only proposition and the author defends a only proposition. Unlike the last category, however, other natures are presented and the borders between their differences are well-marked. Like the other categories, these books are also *cosmopolitan*, because even the authors establish the borders between natures, they assume that only one of them is true and the others have interpretation mistakes already beatted by a pre-post nature.

1° Quadrant: multinatures works are found in the text and the author clearly delimits the borders that distinguish them. Books of this category are the only *cosmopolitical* ones, since there are present many possible natures and the borders and disputes between natures are explicit from the potential and explained limits of each one of them.

Ontological Trajectory Analysis of Actants

Besides analyzing the way how authors present the conflict for composition of ER's common world, we are also interested in verifying which propositions are participating in this conflict and how its ontological trajectory is given. Latour & Woolgar (1986) suppose that textbooks present a discourse yet stabilized, — differently from what, according to them, happens in scientific articles — with a closes vision of Kuhn (1996), who believes that these manuals are how the vigent scientific paradigm is presented to scientist students. Our research, however, indicates that the cenary is more complex, since we find different shapes of ontological trajectories in textbook, at least in relation to ER (Trein et al., 2020; Vazata et al., 2020).

From the classification of statements presented in the books, according to seven propositions described in this chapter, we can observate characteristics of ontological trajectory of ER. A graph in which the horizontal axis represents the statements in chronological sequence and the vertical axis the propositions categories (from the oldest to the youngest), we distinguished five patterns of ontological trajectories, being designated: *(a) Stabilized with history*: the author seems to tell the emergence story of propositions; an ascending story is observed, stabilizing in one of the most recent propositions between the analysided ones; *(b) Stabilized in one proposition*: the trajectory doesn't present a pattern until it stabilize in one proposition; *(c) Stabilized in two or more propositions*: the trajectory doesn't present a pattern until it stabilize between two or more propositions; *(d) Not stabilized in any proposition*: the trajectory isn't stabilized in any moment and proposition; *(e) Mono-proposition*: the graph is a horizontal line emerging from a proposition in relation to the x axis.

Methodological Trajectory

The methodology adopted in this work can be understood as an interpretation of texts (Bakhtin, 2017; Lima et al., 2018). We interpret texts in textbooks and texts from original articles. From the interpolation of these texts, and based on our theoretical framework, we created a text (Ostermann et al., 2023).

This study, in turn, is also a unique production loaded with our surplus of vision, therefore, it is only a possible interpretation of the ontological and discursive structure of undergraduate textbooks. However, such production does not have the same reality and coherence as any interpretation, since in our interpretation we are associated with other networks, which, in turn, will not necessarily be the same as in another interpretation. An interpretation, for example, that was not associated with the original articles would have a smaller network with weaker articulations, which would make it an interpretation with a contracted reality in relation to ours. Below, we describe the methodological trajectory in two parts. The first refers to the data collection process and the second to the data analysis process.

Part 1 — Data Collection

a) Choice of the actant

We chose to analyze electromagnetic radiation due to the fact that, in the context of Modern Physics, its reality is still the result of controversies. In addition, as there are many ER natures, it was necessary to choose some of them. The selected propositions do not reflect the current conceptions of ER, but were chosen due to their pedagogical potential, as they are usually presented in QT subjects (Lima et al., 2020).

b) Choice of analyzed textbooks

The selection of books took place through research of the bibliography prescribed in the syllabus of Quantum Physics subjects at basic and advanced levels in Physics Bachelor's/Licentiate courses in five Higher Education Institutions in Brazil, representing the five regions of the country. They are: Federal University of Rio Grande do Sul (South Region), University of São Paulo (Southeast), Federal University of Pará (North Region), University of Brasília (Center-West Region) and Federal University of Cariri (Northeast Region). We selected the books that appeared most frequently in the menus of these subjects: *Quantum Mechanics* (Cohen-Tannoudji et al., 1991), *Física Moderna* (Caruso & Oguri, 2006), *Quantum Physics* (Eisberg & Resnick, 1985), *Introduction to Quantum Mechanics* (Griffiths, 2005), *Quantum Physics* (Gasiorowicz, 2003), *Quantum Mechanics* (Merzbacher, 1998), *Quantum Mechanics* (Messiah, 1961), *Modern Quantum Mechanics* (Sakurai, 1994).

In order to compose a wide range of analyzed books, we requested indications of books used by Quantum Physics professors at the Physics Institute of the Federal University of Rio Grande do Sul. Suggested books were: *Introductory Quantum Mechanics* (Liboff, 2003), *Quantum Mechanics* (Schiff, 1949), *Conceitos de Física Quântica* (Pessoa Jr., 2003), *Principles of Quantum Mechanics* (Shankar, 1994), *Quantum Mechanics* (Auletta et al., 2009), *Quantum Mechanics* (Blokhintsev, 1964), *Quantum Theory* (Bohm, 1951), *Quantum Mechanics* (Goswami, 1997), *Quantum Mechanics* (Greiner, 2001), *Quantum Mechanics* (Gottfried & Yan, 2003), *Introduction to Modern Physics* (Richtmyer & Kennard, 1947), *Quantum Mechanics Non -Relativistic Theory* (Landau & Lifshitz, 1977), *The Feynman Lectures* (Feynman et al., 2006) and *The Elements of Quantum Mechanics* (Dushman, 1938).

c) Choice of texts

We selected, from the summary, which chapters of each book referred to the description of the selected propositions.

d) Selection of statements

After selecting the chapters, we begin the process of extracting the statements about wave-particle duality. In order to guide the search, we selected some keywords: duality, photon, wave-particle, electromagnetic waves, pilot wave, quantum and corpuscle. After reading the chapter, the statements that contained the keywords mentioned above were cataloged in a table in the order in which they appeared in the book. A table was created for each book. The following is the table prepared for the book *Quantum Physics* (Gasiorowicz, 2003) to exemplify the cataloguing of the statements

Figure 2

Book Analysis Table Quantum Physics (Gasiorowicz, 2003)

Statements	Page	Proposition
Planck obtained this formulaby focusing on the dynamic equilibrium between the emission and absorption of radiation by the walls of the cavity, assumed to consist of simple oscillators. Only by making the radical assumption that radiation of a given frequency v could only be emitted and absorbed in "quanta" of energy given by E = hv could he obtain the distribuction in (1–6).	3	Planck
Einstein considered the implications of having the radiation consist of a collection of quanta of energy hv, where v is the frequency of the light wave. The absorption of a single quantum of radiation by an electron — a process that may take less time than the upper limit previously quoted — increases the electron energy by an amount hv.	5	Einstein
In 1923 de Broglie, guided by the analogy of Fermat's principle in optics and the least-action principle in mechanics, was led to suggest that the dual wave-particle nature of radiation should have its counterpart in a dual particle-wave nature of matter. Thus particles should have wave properties under certain circumstances, and de Broglie suggested an expression for the wavelength associated with the particle.	10	De Broglie
There is no doubt that light consists of individual particles, called photons, which carry energy and momentum, as was first unequivocally demonstrated by the Compton effect.	23	Einstein
The rest of this chapter is devoted to arguments that lead us to the correct form of the linear equation obeyed by ψ(r, t), the Schrodinger equation, the probability for finding an electron at r at a time t in terms of ψ(r, t), and other general properties of the wave function. We shall approach this by constructing waves that might simulate the properties of particles. The study of wave packets will be helpful in this matter, even though the idea that there are real waves that act like particles is not correct.	25	Born

*e) Classification of **statements** according to their proposition*

The categories of propositions are as follows: (1) Classical Undulatory, (2) Corpuscular, (3) Realistic Dualist, (4) Undulating, (5) Probabilistic, (6) Idealistic Dualist, and (7) Hybridization. Utterances that did not contain an ontological description or that did not refer to the propositions described above were disregarded.

Part 2 — Data Analysis

***First analysis**: classification of books in relation to their role in forging the common world.*

We developed an analytical device, summarized in Figure 1. The analysis is divided into two stages:

***1st Stage** — from the cataloging of the propositions, the textbook were divided into:*

— **Mononature**, on the left in the figure: books that present or defend only one proposition.

— **Multinature**, on the right in the figure: books that present two or more propositions.

This classification is based on Latour's science studies and it allows one to realize the ontological commitments of the book.

2nd Stage — *from the analysis of the quoted speech, the textbooks divided into:*

— **Hidden borders**, below in the figure: books **without** a clear structure that separates the pros (separation by paragraph or category); and with the phrases chosen, in relation to the nature of the verbs used, which attributed a **high** degree of reality to a certain proposition, making the others invisible, as in the following: "light **is** composed of corpuscles".

— **Expressed borders**, above in the figure: books **in which there** is a clear structure that separates the propositions; and with phraseological choices, in relation to the nature of the verbs used, that attribute a low degree of reality to the different propositions, enabling the existence of other natures, as in the following example: "**According to Einstein**, light **would be** composed of corpuscles".

Books can therefore occupy one of the four quadrants of Figure 1, named as follows: 4th Quadrant: Multinature cosmopolitan book; 3rd Quadrant: Implicit mononature cosmopolitan book; 2nd Quadrant: Explicit mononature cosmopolitan book; 1st Quadrant: Cosmopolitical book. We stress that this classification is based on Bakhtin's analysis speech and it highlights important political and pedagogic commitments of textbooks, since it reveals the acknowledgment (or not) of plurality in Quantum Theory.

Second analysis: *classification of books in relation to actant stabilization.*

From the classification of the statements, we created a line chart for each book. The x axis represents statements in the order they appear in books, while the y axis represents the seven categories of proposition. The books were classified into the following categories:

a) Stabilize with history;
b) Stabilize on a proposition;
c) Stabilize on two or more propositions;
d) Not stabilized in any proposition;
e) Monoproposition.

Results

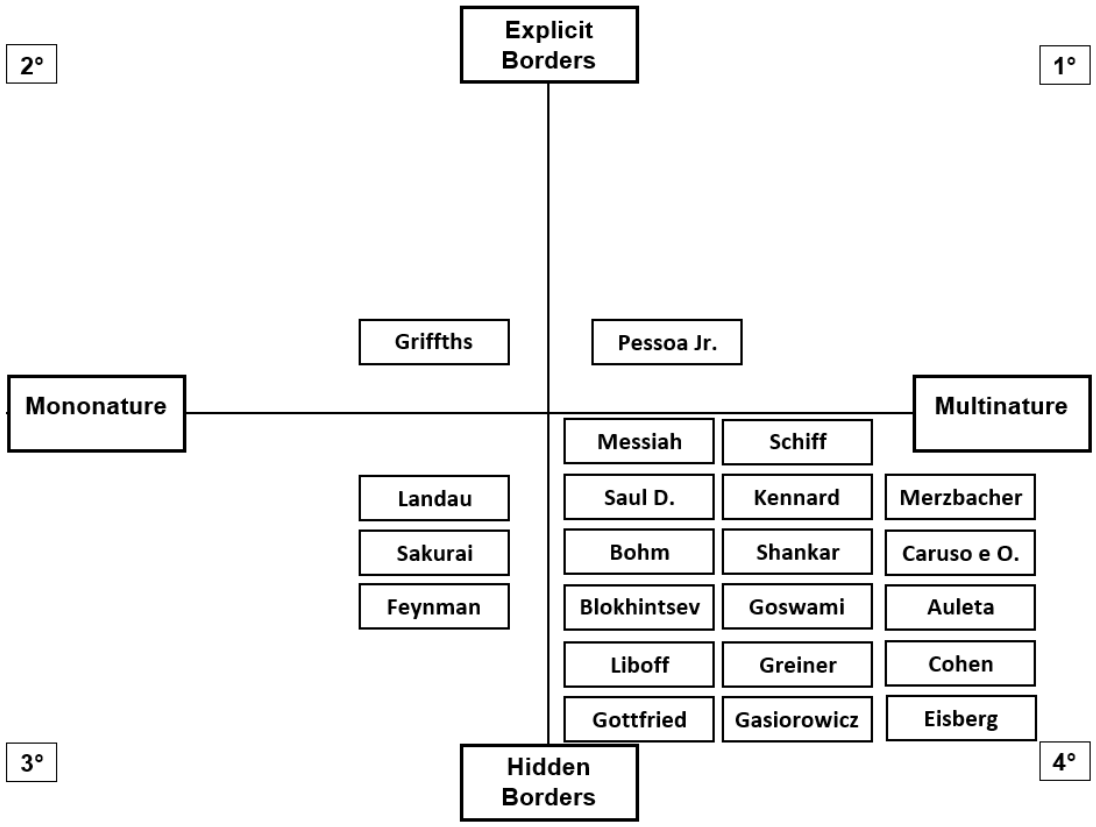
In this section we present the results obtained from the analysis of the text in textbooks. The first part of the results, exposed below, refers to the analysis of the approach of Quantum Mechanics textbooks in the process of composition of a possible common world: cosmopolitan or cosmopolitical. The second part refers to the analysis of the ontological trajectory of propositions.

The Different Natures Incorporated in Textbooks

In our first analysis, we sorted books into one of the four quadrants in Figure 1. Our classification is explained in Figure 2. For each quadrant we bring an exemplification of the book classification process.

Figure 3

Classification of books according to the different possibilities of incorporating the different natures of electromagnetic radiation



4th Quadrant

The fourth quadrant refers to books that present more than one possible nature for ER, and that do not explain the boundaries between the different natures. This is the category with the most cataloged works and seems to be the usual path for undergraduate quantum textbooks. We classify the book *Quantum Physics* (Eisberg & Resnick, 1985), which has been widely used in higher education for decades, in this category. The authors present six of the seven possibilities of the nature of light defined in this article. Proposition 4 — Schrodinger (1926) — was the only one not found. The authors present different propositions and denote a high degree of reality (Latour & Woolgar, 1986).

In the statement below, for example, the authors claim that Compton's experiment provided "**dramatic confirmation**" for Einstein's (1905) proposition.

> "The corpuscular (particlelike) nature of radiation received dramatic confirmation in 1923 from the experiments of Compton. He allowed a beam of x rays of sharply defined wavelength 2 to fall on a graphite target, as shown in Figure 2-5. [...] Compton (and independently Debye) interpreted his experimental results by postulating that the incoming x-ray beam was not a wave of frequency v but a collection of photons, each of energy E = hv, and that these photons collided with free electrons in the scattering target as in a collision between billiard balls. In this view, the "recoil" photons emerging from the target make up the scattered radiation." (Eisberg & Resnick, 1985, p. 34)

However, in a later passage, the authors state that it is only possible to describe the behavior of light from the complementary views of wave and particle, and its nature is defined by measurement, according to the proposition of Niels Bohr (1928). The authors attribute a high degree of reality to this proposition, as highlighted in the following excerpt: "if a measurement **proves the wave character** of radiation or matter, then it **is impossible to prove the particle character** in the same measurement and vice versa.". In other words, the authors emphasize that considering only the wave or corpuscular character is an incomplete conception of the reality of radiation. In the last line the authors resume "radiation and matter are **not simply** waves **or simply** particles."

> "Neils Bohr summarized the situation in his principle of complementarity. The wave and particle models are complementary; if a measurement proves the wave character of radiation or matter, then it is impossible to prove the particle character in the same measurement, and conversely. Which model we use is determined by the nature of the measurement. Furthermore, our understanding of radiation, or of matter, is incomplete unless we take into account measurements which reveal the wave aspects and also those that reveal the particle aspects. Hence, radiation and matter are not simply waves nor simply particles." (Eisberg & Resnick, 1985, p. 63)

As propositions defended in the proposals presented are ontologically contradictory, since Einstein's proposition is corpuscular and realistic, while Bohr's is dualist and idealist. The author, therefore, categorically states that the nature of light is corpuscular, at the same time that he claims that it is dualistic, without, however, enabling the possibility that they can coexist or that they have some kind of limitation in the explanation of phenomena. From this analysis we can highlight some conclusions about this category:

— Although the authors present different natures for the ER, they hide that there are disputes between them, since: there are no comparisons between them; there is a high degree of reality to both; there is no clear structure that distinguishes or classifies them.

— They are **ontologically contradictory** since they attribute a high degree of reality to antagonistic natures.

— Their approach is cosmopolitan, as they do not present controversies between natures and act as if there were a pre-posted nature.

From the perspective of Bakhtinian philosophy, to hide the *borders of the speech* may be associated to an authoritarian perspective. By doing so, the authors depict a proposition that was locally uttered as an objective fact. This erasing is exactly what Latour calls as the black boxing process (Latour, 1999). This could be acceptable when one deals with stabilized facts, in the case of Quantum Theory, however, there are multiple possible ontologies that textbooks evoke without making them explicit. In Bakhtinian terms, their utterance may be associated to a *speech project* that is committed to an authoritarian, linear and rational science.

3th Quadrant

The third quadrant refers to books that present only one proposition for electromagnetic radiation, without showing that there are other possibilities of nature. The book *Modern Quantum Mechanics* (Sakurai, 1994) was classified in the category. Only two statements were found in the book, which may illustrate that, for the author, the proposition of Born (1926), defended in the book, is already stabilized, that is, there is no need to argue in its defense.

The following excerpt reflects the author's view, he assumes that the square modulus of the wave function is the "**most satisfactory**" interpretation of the Schrodinger wave function, that is, it seems to suggest that there may be other possible interpretations for the Schrodinger wave function wave ψ, however, does not present any other proposition.

> "An atomic electron is to be regarded as a continuous distribution of matter filling up a finite region of space around the nucleus; yet, when a measurement is made to make sure that the electron is at some particular point, this continuous distribution of matter suddenly shrinks to a pointlike particle with no spatial extension. The more satisfactory statistical interpretation of $|\psi|^2$ as the probability density was first given by M. Born." (Sakurai, 1994, p. 102)

Furthermore, according to the author, it is the measurement process that causes matter distributed in space to "shrink" into a particle. In this way, the author defends his own conception of nature, a hybridization of the propositions of Born (1926) and Bohr (1928). From this analysis we can highlight some conclusions about this category:

— They present only one nature of the ER, which is a hybridization of the propositions found in the seminal articles.

— It is **ontologically coherent**, because only one nature is presented.

— Their approach is **cosmopolitan**, as they start from a pre-posted nature.

Again, we have the complete erasing of *speech borders* as well as of any competing *voice*. This stylistic and thematic choice also reveals a *speech project* with a strong commitment with an authoritative and rational science.

2nd Quadrant

The second quadrant refers to books that defend only one proposition for electromagnetic radiation, showing that there are other possibilities of nature. The work *Introduction to Quantum Mechanics* (Griffiths, 2005) was the only one cataloged in this category. The author presents different propositions at the beginning of the work, but soon assumes his mononature position.

In the quote below the author explains his position. He understands that there are at least three possibilities of the nature of ER: realistic (we classify it as the proposition of Einstein (1905)), agnostic (position that, according to the author, refuses to give an answer) and orthodox (which corresponds to the proposition adopted and elaborated by the author himself).

> "Until fairly recently, all three positions (realist, orthodox and agnostic) had their partisans. But in 1964 John Bell astonished the physics community by showing that it makes an *observable* difference whether the particle had a precise (though unknown) position prior to the measurement, or not. Bell's discovery effectively eliminated agnosticism as a viable option, and made it an experimental question whether 1 or 2 is the correct choice. I'll return to this story at the end of the book, when you will be in a better position to appreciate Bell's argument; for now, suffice it to say that the experiments have decisively confirmed the ortodox interpretation: a particle simply does not have a precise position prior to measurement, any more than the ripples on a pond do; it is the measurement process that insists on one particular number, and thereby in a sense creates the specific result, limited only by the statistical weighting imposed by the wave function." (Griffiths, 2005, p. 4)

According to the author, of the three propositions, the orthodox is the only one that corresponds to a reality, since "experiments **decisively confirmed** the orthodox interpretation". The orthodox position is a hybridization of the propositions of Born (1926) and Bohr (1928), since the Born equation describes the probable position of the particle, and that the "measurement process […] creates the specific result", as prescribes Bohr. Before measuring it is impossible to pinpoint the position of the particle.

The author, therefore, initially presents some possible propositions, but assumes that only one of them has the necessary empirical proofs for its existence. It differs from previous authors by accepting the possibility of other natures, however, it can be understood that in the author's view the other propositions contain errors of interpretation, through empirical proof. From this analysis we can highlight some conclusions about this category:

— Unlike the previous quadrants, the work ontologically describes different propositions and makes their differences explicit. The demarcation of borders is evident in the structure of presentation of the propositions in which the author not only highlights that there are three possibilities, but also presents them in a categorized way, separated by subsequent paragraphs.

— The statements of the propositions are presented with different degrees of reality, and the discourse of one of the propositions has an expanded reality in relation to the others, therefore, it is **ontologically coherent**.

— His approach is **cosmopolitan**, because only one of the natures has reality.

Differently from the previous two categories, in this quadrant the *speech borders* are revealed and the plurality of conceptions is recognized. In this sense, this *speech project* is less authoritarian than the others but it still points to the necessity of one

single reality and, thus, it does not deepen the debate about the competition between different ontologies. In this sense, the utterance characteristics are still committed to an authoritarian, linear and rational science, although it presents already the acknowledgement to some internal plurality.

1st Quadrant

The first quadrant refers to books that present more than one nature for electromagnetic radiation, and that explain the boundaries between the different natures. The only book reviewed that fell into this category was the book *Conceitos de Física Quântica* (Pessoa Jr, 2003).

In the excerpt below, in the presentation of the structure of the book, the author assumes the possibility of incorporating different natures for quantum phenomena:

> "Conceptual and philosophical problems, normally avoided in such courses, are tackled *con gusto* in the present book. The main key to unraveling such problems is to recognize from the beginning that there are different plausible interpretations of Quantum Theory, all with their merits and anomalies. Armed with such worldviews, the student can understand different experiments that are conceptually simple […]" (Pessoa Jr., 2003, p. 1, our translation).

Based on this principle, the author separates the different natures into groups. According to the author, "There are dozens of different interpretations of Quantum Theory, which can be grouped into four or five large groups[3]. We will now present as four basic interpretations […]." (Pessoa Jr., 2003, p. 5, our translation). The author divides them into the following groups: (i) undulating; (ii) corpuscular; (iii) realist dualists and (iv) positivist dualists. Based on these categories, the author develops the concepts of Quantum from the explanation of quantum phenomena, each one being analyzed according to the four categories. Below is a description of a category:

> "(1) Wave Interpretation (we will consider here Erwin Schrödinger's idea that quantum objects are actually waves, bringing it closer to John von Neumann's view that introduces wave collapses). Before detection, the quantum object propagates as a wave, but during detection it becomes more or less well located, looking like a particle. There is no longer any contradiction, because for a while we have a scattered wave, and then we have a particle (or rather, a very narrow wave packet), without both coexisting simultaneously." (Pessoa Jr., 2003, p. 5, our translation)

The first highlight is in relation to the presentation structure of the categories. Note that the author adopts a clear spatial division of the description of the categories, numbering them from (1) to (4), and separating them in subsequent paragraphs. In the excerpt, "we will **consider** here the idea of Erwin Schrodinger", the author suggests that this is just a possible wave nature, which denotes a low degree of reality given to the proposition.

In presenting another category, the author follows a logic of ontological description "(2) Corpuscular interpretation (defended for example by Alfred Landé, and more recently by Leslie Ballentine). The photon and electron would actually be a particle, which is manifest when we detect it." (Pessoa Jr., 2003, p. 5, our translation). As in the description of the previous category, the author also presents some scientists who defend this proposition and highlights that "The photon and the electron **would** actually be a particle", that is, the author assumes that according to these physicists who defend this proposition the ER **would be** a particle, which does not mean that light **is** a particle. From this analysis we can highlight some conclusions about this category:

— The structure of this work does not allow an analysis equal to that of the other books, since the author groups different propositions in a single category and takes them up again in several chapters.

— Since all the phenomena presented in the book are analyzed according to each category, it can be inferred that there is **no ontological stabilization** of any proposition (or of any category of propositions). Furthermore, the author assumes from the beginning that QT is not ontologically stabilized.

— The author presents different natures and explicitly demarcates their boundaries. This characteristic can be observed through the spatial distribution of descriptions in well-defined categories.

— It presents statements about the different propositions with a low degree of reality, which denotes an **ontological coherence**.

This is the only **cosmopolitical** approach not only because it addresses different ontologies but also because it makes the speech borders explicit. It does not start from a pre-posted nature, in addition, it seeks to stop the composition of a "common world" in relation to the ontology of ER. This book allows the reader to understand the different cosmoview as well as to recognize their origins, without erasing differences and disputes. According to Bakhtin's Philosophy, such stylistic and thematic choice may be associated to a project speech that is committed to build an anti-authoritarian, non-linear and non-rational science.

Ontological Trajectory of Propositions

In this section we analyze the ontological trajectory of the different propositions of electromagnetic radiation in textbooks. From the argumentation of the graphs, we identified five patterns of ontological trajectories. In each group, the books that follow the corresponding pattern are described, as well as the analysis of the graphic of one of the works. Our proposal is to observe whether there is ontological stabilization of the propositions (Latour, 1999) and how they are developed by the authors.

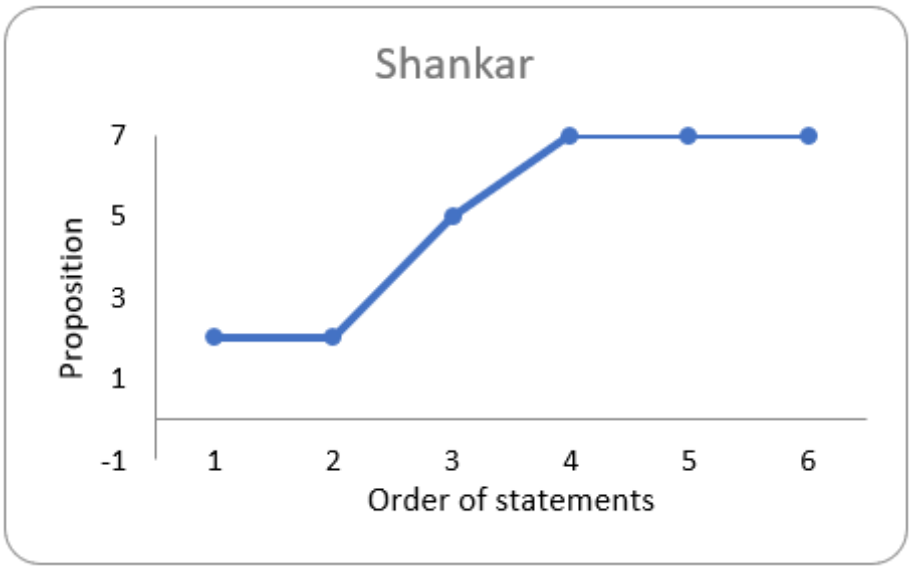
a) Books that stabilize with history

This category includes books whose ontological trajectory described in the graph corresponds to an ascending line. The authors seem to "tell the chronological story" of the propositions of Quantum Theory. The graph in Figure 3 presents the ontological

trajectory of the book *Principles of Quantum Mechanics* (Shankar, 1994). The author first presents Einstein's proposition (1905), then Born's proposition and stabilizes in a new proposition, which corresponds to the hybridization of De Broglie (1923, 1924) and Born (1926). In the graph, stabilization corresponds to a horizontal line.

Figure 4

Graph referring to the book Principles of Quantum Mechanics (Shankar, 1994)



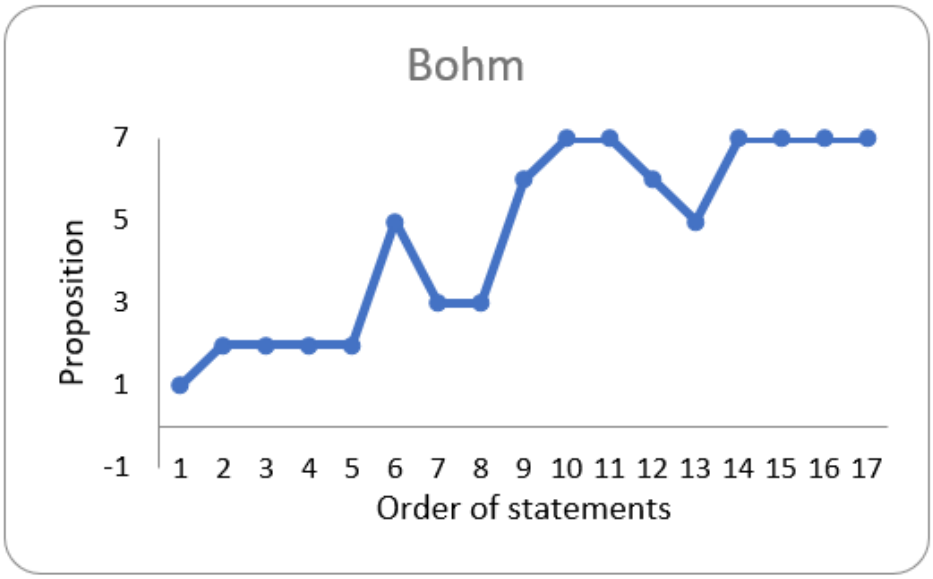
In addition to the book analyzed above, the work of Blokhintsev (1964) fits into this group.

b) Books that stabilize in a proposition

In this category are the books that, at the end of the ontological trajectory, stabilize in a proposition. The book *Quantum Theory* (Bohm, 1951), depicted in the graph in Figure 4, is an example of this category. Unlike books in the previous category, there is no upward trajectory; the graph line follows an unpatterned path until it reaches the end of the path, when the line becomes a horizontal line. David Bohm's book presents six different propositions and settles on a hybridization of Born (1926) and Bohr's (1928) propositions.

Figure 5

Graph referring to the book Quantum Theory (Bohm, 1951)



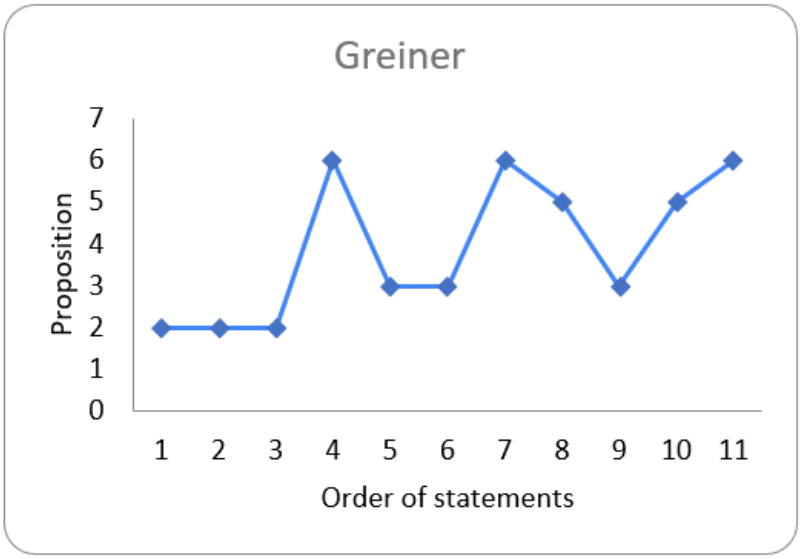
This category also includes books by Caruso & Oguri (2006), Gasiorowicz (2003), Gottfried & Yan (2003), Merzbacher (1998) and Schiff (1949).

c) Books that stabilize on two or more propositions

As an example of a book that stabilizes in more than one proposition, the graph in Figure 5 brings the work *Quantum Mechanics* Greiner (2001). The author starts the text by presenting Einstein's proposition (1905), but from the fourth statement he stabilizes around the propositions of De Broglie (1923, 1924), Born (1926) and Bohr (1928). As the author adheres to more than one proposition, the ontological stabilization pattern is not a horizontal line, as in the cases of the previous categories, characterized by ascending and descending lines around the three propositions.

Figure 6

Graphic referring to the book Quantum Mechanics (Greiner, 2001)



The books Cohen-Tannoudji et al., (1991), Eisberg & Resnick (1985), Goswami, (1997), Liboff (2003), Messiah (1961) and Dushman (1938) also fall into this category.

d) Books that do not stabilize in any proposition

This category includes books that, at no time, present ontological stabilization. The work *Quantum Mechanics* (Auletta et al., 2009) described in the graph in Figure 6 is an example of this category. Of the seven possible propositions, only that of Schrodinger (1926) is not present. There are ascending and descending lines along the entire ontological trajectory, but unlike what was observed in the category above, there is no pattern in the presentation of propositions, so there is no stabilization.

Figure 7

Graphic referring to the book Quantum Mechanics (Auletta et al., 2009)

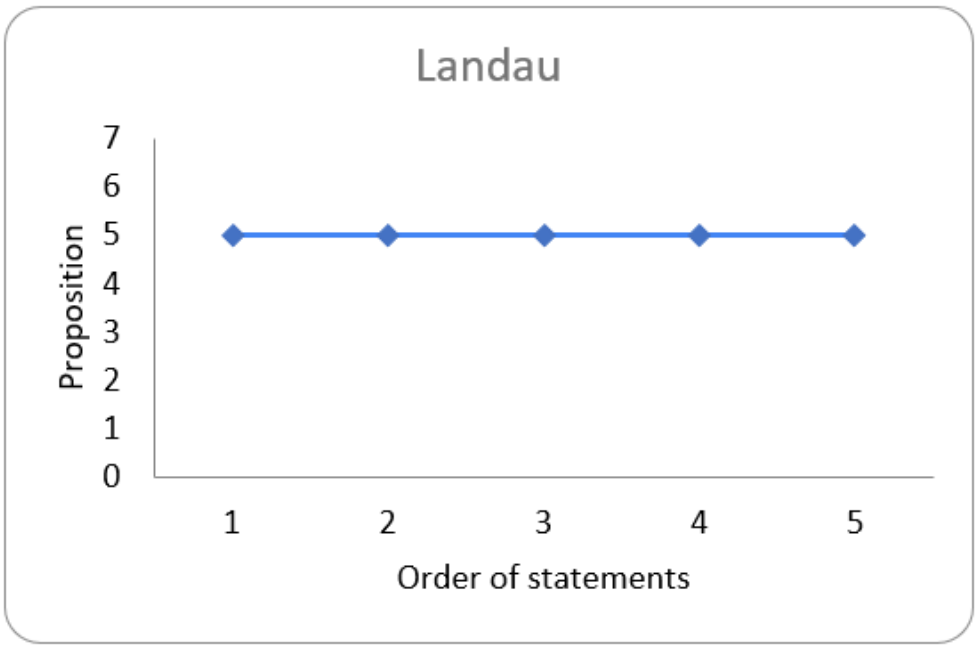
Richtmyer & Kennard (1947) also falls into this category.

e) Books that present only one proposition

The last category refers to books that present a stabilized proposition from the beginning. In the case of the work *Quantum Mechanics Non-Relativistic Theory* (Landau & Lifshitz, 1977), described in the graph of Figure 7, the authors adhere to Born's proposition (1926). The graph in the book therefore presents only a horizontal line.

Figure 8

Graph referring to the book Quantum Mechanics Non-Relativistic Theory (Landau & Lifshitz, 1977)



The work *Modern Quantum Mechanics* (Sakurai, 1994) and *The Feynman Lectures* (Feynman et al., 2006) has an ontological trajectory structure identical to the book presented above, as can be seen in the graph in Figure 4. However, *Introduction to Quantum Mechanics* (Griffiths, 2005) has a different pattern. As discussed in the previous section (in the presentation of quadrant 2), the author explicitly presents different possible natures for ER, but assumes that only one of them corresponds to a reality. Thus, even if more than one proposition is present in its trajectory, the work still falls into the category of monoproposition.

Final Considerations: The Photon is Naked

The results found in our analysis of the textbook indicate that there is not an ontologically stabilized ER proposition, when we consider all the books. However, since most of these same books hide the boundaries between the propositions, what we can associate to an authoritarian perspective according to Bakhtinian analysis, it is evident that the authors simulate that there is a consensus within the scientific community regarding their ontology.

We propose an analogy between the results found in this work and a Danish tale from the beginning of the 19th century. In the story there was a very vain king who loved new clothes. One day two crooks, posing as tailors, offered the king a garment made of a very special fabric, so special that it was invisible to all who were foolish or presumptuous. The story of such an outfit quickly spread across the kingdom. The king then began to invite people connected with the administration of the kingdom to accompany the manufacture of clothing. Everyone watched the weavers weaving an "invisible" garment, but fearful of being called fools, and thus removed from their duties in the high dome of the kingdom, they praised the garment for the king, even without seeing it. Very curious about the clothing, one day the king himself went to investigate the work of the tailors and he himself, afraid of giving a negative image to the kingdom, because he also did not see the clothes, praised the work of the crooks. On the day the garment was ready, the crooks helped the king to "dress" it. Completely undressed, the king went out into the street for the procession of his new clothes. In the street, a crowd began to exclaim the most beautiful compliments about his clothing, until in a moment a child shouts "the king is naked". The people immediately began to whisper "the king is naked", "the king is naked".

In the story by the Dane Hans Christian Andersen, entitled The King's New Clothes (McKissack et al., 1987), adults, fearful of being labeled as stupid and incapable, pretend to see the king's clothes, while the child, who does not care in keeping up any kind of appearance, he says the obvious: the king is naked. In a way, this tale challenges the view of technocratic superiority, as it is often non-experts (like a child) who point to a reality that no one wants to see.

In this sense, the child in the tale can be compared to the conceptual character of Gilles Deleuze: the Idiot. The Idiot "is the one who always slows others down, the one who resists the way the situation is presented" (Stengers, 2007, p. 444, our translation). In our metaphor, textbooks simulate the existence of a stabilized reality for the nature of the photon, that there is a common world, even if there is no indication of a consensus. The photon is undressed, no clothes fit it properly. We need a child (or an idiot) to scream "**the photon is naked**", "the ER is not stabilized", "there is no common world".

The false stabilization of the photon, found in textbooks, is the result of an authoritarian and cosmopolitan conception of science that it translated to the concrete text by easing speech borders and by ignoring the internal plurality of science. In this sense, cosmoview perspective and speech style are never dissociated (Bakhtin, 1986b). In this context, the role of contemporary textbooks is to put an end to discussions, even if for that they have to sacrifice ontological coherence and/or renounce the multiple realities that allow, together, a more adequate explanation of quantum phenomena. The discursive resources used by the authors, attributing a high level of reality to antagonistic ontologies, are intended to erase the internal discussions of scientific culture, and therefore fit within the perspective of hegemonic education, which aims to train "experts" and citizens who understand science as a source of universal, technical

and neutral knowledge, aligned with rationalist and positivist conceptions of science. In it is important to notice that this ideological defense is present in the text in many different levels, including its stylistic choices and mainly by recognizing what it denies to speak, something that we are invited to investigate by Bakhtin's Philosophy (Bakhtin, 2017).

In order to promote an anti-authoritarian view of science, we need to bring up discussions around non-stabilized nature, thus promoting a counter-hegemonic education (Apple, 2018), with the purpose of training Deleuzian Idiots, who understand the science as a cultural activity associated with the social issues of its time, respecting the ontological and epistemological diversity of the world. This counter hegemonic education must not only address a new perspective splicitly as well as adopt new discursive styles that are consistent with it.

In this paper we present a study on the discursive resources used by authors of undergraduate Quantum Physics textbooks, in order to analyze the ontological trajectory of ER and investigate the way in which the different natures of the ontology of light are incorporated in these books. Our study demonstrates that the analyzed textbooks differ in four ways of incorporating the reality of light and are divided into five groups in relation to the way of presenting their ontological trajectory.

First research question: all the books previously selected for analysis are based on a cosmopolitan structure, that is, they assume that there is a unique and transcendent nature. **Second research question:** our research points out that the discursive style of the fourth quadrant is probably the usual way to incorporate the nature of light, since the category has a much higher number of textbooks compared to the others. Third research question: from the analysis of the *cited discourse,* we found that the authors of the books in this category are ontologically contradictory, since even if the books are cosmopolitan, they attribute a high degree of reality to antagonistic natures. Furthermore, our studies indicate that, unlike what Latour and Woolgar supposed, only three of the twenty-two analyzed books present a stabilized discourse throughout the entire work, with two books not even stabilizing any proposition and only six textbooks stabilizing in a single proposition.

Fourth research question: within this scenario, the textbook has the authoritarian role of closing the internal discussions of the scientific culture. We understand, therefore, that there is a need for a counter-hegemonic narrative, in order to form "Idiots". We therefore need a deep cultural review, not only in content, but in compositional structure (with a structure that distinguishes and points out the differences between ontologies) and style of the quoted discourse (with ontologically coherent enunciations), in order to found a new didactic discourse genre. Thus, we need to go beyond the presentation of contents, exploring in an anti-authoritarian way the plurality of realities that make up the spectrum of the ontology of science, with the purpose of discussing topics related to the philosophy of science, as well as its role in the structure of society.

We emphasize that when we create categorizations and classifications in such a diverse and complex universe, such as that of QT, we inevitably leave out important elements. Among the reasons that make this activity complex, two stand out: first, there are many proposals of the nature of light, therefore, it is necessary to create exclusion criteria; second, many proposals have approximations, which eventually makes it difficult to differentiate them when classifying the statements. Furthermore, we emphasize that our purpose in this research is to propose a way to visualize and address the controversies around the problem of wave-particle duality in the scientific-pedagogical context, so we do not intend to exhaust any discussion, but to promote it.

Finally, as we have mentioned, there are many works that address the different conceptual and political problems related to textbook. In the present paper, however, the combination of Latour's Science Studies and Bakhtin's Philosophy allowed us to connect the style of the texts with ontological and political commitments in the case of Quantum Mechanics. These results point to the fact that most textbook lead to an authoritarian, cosmopolitan and restrictive conception of science. In order to promote a diologic and cosmopolitical education, on the other hand, one has to assume a different discursive standpoint and, thus, our research corroborates the idea that Science Education needs to renew its styles of texts in the classroom (Batista et al., 2015; Lima et al., 2020; Setlik, 2022).

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