EDGAR MORIN'S COMPLEX THINKING AND PHYSICS TEACHING: MAPPING OF BRAZILIAN THESES AND DISERTATIONS

O PENSAMENTO COMPLEXO DE EDGAR MORIN E O ENSINO DE FÍSICA: MAPEAMENTO DAS TESES E DISSERTAÇÕES BRASILEIRAS

EL PENSAMIENTO COMPLEJO DE EDGAR MORIN Y LA ENSEÑANZA DE LA FÍSICA: MAPEO DE TESIS Y DISERTACIONES BRASILEÑAS

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How to refer to this article:

MESQUITA, A. C., FORTUNATO, I., CRUZ, J. A. S. Edgar Morin's complex thinking and physics teaching: Mapping of brazilian theses and disertations. **Rev. Educação e Fronteiras**, Dourados, v. 13, n. 00, e023006, 2023. e-ISSN: 2237-258X. DOI: https://doi.org/10.30612/eduf.v13i00.16922

| **Submitted**: 25/11/2022
| **Revision required**: 27/12/2022
| **Approved**: 19/01/2023
| **Published**: 29/03/2023

Editor: Profa. Dra. Alessandra Cristina Furtado

Executive Deputy Editor: Prof. Dr. José Anderson Santos Cruz

ABSTRACT: This study presents an overview of the research developed with the complex thinking approach in Physics teaching as a theoretical contribution to this theme. A state of knowledge was produced from the Brazilian Digital Library of Theses and Dissertations (BDBT) to select the works that meet the listed criteria, followed by process of systematization of technical and analytical data that organized the productions according to the objectives, methodology, data collection, and main results achieved. Only one thesis and four dissertations were located, totaling five (05) mapped research. Ultimately, we aim to bring an approach between complex thinking, science, and teaching to bring a broader vision of knowledge and reflection about the current educational models, showing a possible path to humanized pedagogical innovation.

KEYWORDS: Mapping. Complexity. Education. Physics teaching.

RESUMO: *Este estudo apresenta um panorama das pesquisas desenvolvidas com a abordagem do pensamento complexo na área do ensino de Física, como contribuição teórica nesse tema. Foi produzido um estado do Conhecimento a partir da Biblioteca Digital Brasileira de Teses e Dissertações (BDBT) para seleção dos trabalhos que atendem aos critérios elencados, etapa seguida de um processo de sistematização dos dados técnicos e analíticos que organizou as produções de acordo com os objetivos, metodologia, coleta de dados e principais resultados alcançados. Foram localizadas apenas uma tese e quatro dissertações, totalizando cinco (05) pesquisas mapeadas. Ao final, almeja-se uma aproximação entre o pensamento complexo, a ciência e o ensino para trazer uma visão mais ampla acerca do conhecimento e a reflexão diante dos atuais moldes educacionais, demonstrando um possível caminho à inovação pedagógica humanizada.*

PALAVRAS-CHAVE: *Mapeamento. Complexidade. Educação. Ensino de física.*

RESUMEN: *Este estudio presenta un panorama de la investigación desarrollada con el enfoque del pensamiento complejo en el área de enseñanza de la Física, como aporte teórico sobre este tema. Se elaboró un estado de conocimiento a partir de la Biblioteca Digital Brasileña de Tesis y Disertaciones (BDBT) para la selección de trabajos que atiendan a los criterios enumerados, paso seguido de un proceso de sistematización de datos técnicos y analíticos que organizó las producciones de acuerdo con los objetivos, metodología, recopilación de datos y principales resultados obtenidos. Solo se localizaron una tesis y cuatro disertaciones, totalizando cinco (05) levantamientos mapeados. Al final, pretendemos unir el pensamiento complejo, la ciencia y la enseñanza como una forma de acercar una visión más amplia del conocimiento y la reflexión sobre los modelos educativos actuales, mostrando un camino posible hacia la innovación pedagógica humanizada.*

PALABRAS CLAVE: *Mapeo. Complejidad. Educación. Enseñanza de la física.*

Introduction

This article was designed to present and analyze issues, thematic trends, methodologies, and results related to the academic production of Physics teaching in theses and dissertations that have appropriated contributions from studies about complexity theory, specifically those developed by Edgar Morin. This systematic review aims to analyze how and to what extent complex thinking can influence teacher education in Physics undergraduate courses, strengthening human formation.

The idea for constructing this survey emerges from a reflective and inflexive look at the daily life of a teacher trainer, whose job is to teach Education subjects in an undergraduate degree in Physics (FORTUNATO, 2022). In this examination of daily life, elements that are already known were addressed, such as the need for interdisciplinary dialogue, the teaching of sciences focused more on human aspects that surround technical knowledge, the placement of the study of humanities as something irrelevant to the technological and neoliberal society we have. Nevertheless, beyond listing these already known things and lamenting what we have, we sought to identify clues as to why the areas are arbitrarily separated. Hypotheses were put forward, and it was concluded that the discourse demonstrating the importance of returning to a complex understanding of the world is welcomed as verbiage yet ignored in everyday life that insists on producing a growing abyss between science/technology and an islet that calls itself humanities.

Beyond daily life as evidence, the work "The seven-knowledge necessary for the education of the future", written by Morin (2000) at the end of the last century, is worth mentioning. This work was inserted in a context of (re)formulations of the human project through Education, which, after the holocaust, the Cold War, sustainable development, and commercial internet, was being woven in the name of a "planetary citizenship". As citizens of the world, the planet would be the home of all people and all forms of life, with respect for the rights and duties of this planetary community.

Achieving what Morin (2000) says requires open and complex educational processes that channel efforts in consolidating proposals that encourage awareness and participation of the elements involved in the educational activity. In this sense, the author highlights the need to rethink scientific knowledge from a complex perspective, reflecting the role of knowledge in society and going beyond exclusively objective, concrete, and deterministic evidence. The ideas

contained in this work, written in a more prosaic language with the purpose of wide dissemination, are widely accepted, but only as an enunciation.

This is because the educational reality in most schools reveals that pedagogical practice is supported by reproductive and conservative teaching. This perception intensifies when we look at the subject of Physics, as reported by Marco Antônio Moreira (2021), in which concepts are commonly worked with the transmission of knowledge by the teacher to students, passive receptors in this relationship. Considering the Physics teaching practiced in most situations, it can be seen that there is an emphasis on the memorization of contents and algebraic resolution of problems disconnected from the reality experienced by students. Finally, there is the presentation of laws, formulas, concepts, and meanings emptied of meaning by adopting practices that favor theory and abstraction, emphasizing memorization and excessive handling of formulas in strictly didactic and artificial circumstances.

According to Moreira (2021), all this is due to the goals imposed on educational institutions: good results in examinations (internal, external, local, and international). Thus, there is a contradiction between complexifying teaching for a global understanding of planetary life and simplifying things so that one can answer the questions of a test. No "teaching for testing", to use the author's words, can insert the ideas of global citizenship into their daily lives - there is no time or place for anything other than the transmission of the curricular elements that will later be verified in some examination, either in the classroom itself, or for approval at another level of study or for employment, or to measure some supposed quality of education in local or global comparison.

In this context, some concerns have arisen that have instigated us to deepen our studies relating complex thinking to Physics Teaching to establish more meaningful, contextualized, and humanized teaching and learning practices by understanding Physics as a subject in a permanent relationship with reality and with other historical, artistic, philosophical, and linguistic knowledge. For example, is it possible to work with Physics concepts from the complex thinking perspective? In what aspects can complex thinking influence teaching practices in the Physics curricular component? What is the influence of this theoretical strand in the training of future teachers in this area of knowledge?

We have organized this article into three sections to provide meaningful answers and meet the main objectives defined for this mapping. We begin with the first section, bringing elements of the theoretical framework built by Edgar Morin when relating complexity to education, aiming to support the ideas and conclusions from the analysis performed. The second

section describes the methodological procedures used in this systematic survey and ends with a quantitative analysis of the works used in the state of knowledge. Finally, the third section contains the qualitative analysis of the surveys, revisiting their objectives, methodology, the subjects participating in the surveys, and their results, consolidating the state of knowledge.

It is expected that the discussions and the forwardings fomented may contribute to the recognition of the relevance of the ideas formulated by Edgar Morin for the educational field and, particularly, for the processes of teaching and learning Physics, expanding the reflections in this perspective as an essential step in the search for a more practical education, contextualized and following the current demands that present themselves with the advent of modernity.

Complexity theory and other education

Morin (2000) presents complex thinking as a theory that breaks away from the paradigm of knowledge simplification in the sense of encouraging the establishment of links between knowledge from different areas. This vision opposes classical thinking, which has been rooted in the sciences for many years and is based on the fragmentation of knowledge and rationality. When dealing with this classical thinking, the author defines it as governed by three pillars, comparing each of them with complex thinking, which he calls the "three pillars of certainty": the principle of order, the principle of separability, and the principle of absolute reason.

The principle of order explains that there is an absolute order to be found behind all disorder since the universe and society are governed by deterministic laws (MORIN, 2000). The author argues that complex thinking does not aim to replace confusion with an order but cites a dialog between order, disorder, and organization. It is posited that everything comes from disorder because "it is by disintegrating that the cosmos organizes itself" (MORIN, 1991, p. 65, our translation).

As continuity to the principles that underlie classical thinking, we have the second item, separability. This idea originates in the specialization and fragmentation of knowledge, which are increasingly isolated and specific, disregarding the multiple relationships established with the context that permeates the object of study. In contrast, Morin (2000) reinforces the inseparability of knowledge in the complex perspective by understanding reality through the interaction between the elements that compose it.

The third pillar of certainty, the principle of reason, establishes the disregard of mistakes, uncertainties, and contradictions in knowledge construction since the source of

knowledge is, in fact, objectively described without the interference of subjective aspects. Complex thinking, in turn, recognizes the limits of the approach presented in a "ceaseless coming and going between certainties and uncertainties, between the elementary and the global, between the separable and the inseparable" (MORIN, 2000, p. 200, our translation).

These three pillars of certainty, as outlined by Morin (2000), consisted of points of support for classical thought and science, one of the great narratives of humanity, which aimed to conceive certainty marks for human life itself. Here we do not intend to engage in a discussion of paradigms or even of historical denominations of society (such as modern, contemporary, post-modern, hyper-modern, etc.) but rather to agree with the idea that the great narratives that ground human life and guarantee its future, such as science, religion, enlightenment, capitalism, and so on. These collapsed in the 20th century with the First World War, the 1929 crisis, the holocaust, and the cold war (LYOTARD, 2009).

Thus, these most extreme events of human violence against humanity and all planetary life have become motivators of various social and academic movements that tend to refute the structuralism intended by the grand narratives, including the idea that everything can be understood, explained, and controlled through reason. Thus, the pillars and classical thought are structurally shaken with the advent of concepts such as disorder, non-separability, non-reducibility, and logical uncertainty, characteristics of complex thinking which seek to (re)unite what was arbitrarily separated.

Based on these oppositions, Morin (2000) defines the organizational operators of complex thinking: as the dialogic operator, the recursive operator, and the hologrammatic operator. The Dialogic Operator aims to unite antagonistic concepts but inseparable from the understanding of reality in its totality. According to the author, this principle "unites antagonistic notions to think about the organizing, productive, and creative processes in the complex world of life and human history" (MORIN, 2000, p. 204, our translation), such as reason and emotion.

The Recursive Operator overcomes the notion of cause and effect in linearity, considering that we are products of a system that we produce and that effects can be producers of their causes, that is, the uncertainties and indetermination of a process in the constant modification are considered. For Morin (1990, p. 108, our translation), a recursive process is one in which "products and effects are, simultaneously, causes and producers of that which produced them".

The Hologrammatic Operator relates to the conception that the whole and its parts constitute themselves through the relationships that unite them. A hologram is an image in which each part contains revelations about the whole it is composed of, thus denominating this principle because it means that "not only the part is in a whole, but that the whole is inscribed, in a certain way, in part" (MORIN, 2005, p. 302, our translation). To exemplify, Morin (2005) cites cells, components that carry almost all the information about each human being. Added to the Dialogical and Recursive Operators, the Hologrammatic Operator brings the idea of totality while considering the existence of parts.

The relationship between these operators forms the basis of complex thinking. Morin (1998, p. 138, our translation) points out that "complex thinking while aspiring to multidimensionality, has at its core a principle of incompleteness and uncertainty". When reflecting on the issue of totality and the importance of overcoming knowledge fragmentation, Morin (2000) composes the seven pieces of knowledge necessary for the education of the future in one of his best-known works for the educational field as a way to widely disseminate his findings on complexity, built up over decades and decades of study. This knowledge is combined with the need to reform education, seeking the "open totality of the human being and not just one of its components" (MORIN, 2000, p. 11, our translation). The author justifies this aspect by pointing out that:

> We must, therefore, think about the problem of teaching, considering, on the one hand, the increasingly severe effects of the compartmentalization of knowledge and the inability to articulate them with each other; on the other hand, considering that the ability to contextualize and integrate is a fundamental quality of the human mind, which needs to be developed and not atrophied (MORIN, 2003, p. 16, our translation).

The seven knowledge anchors this change of vision on the act of educating (MORIN, 2000), summarized below:

I- "The blindnesses of knowledge: error and illusion": recognize knowledge as an interpretation of reality and points out the fundamental need to recognize the error in these elaborations about reality.

II- "The principles of pertinent knowledge": it places the essentiality of contextualizing all available data when trying to understand a given problem, opposing the idea of fragmentation and specialization of knowledge without, however, rejecting the already organized disciplines.

III- "Teaching the human condition": this should be the beginning and the end of human communication; it implies putting oneself in the place of the other, trying to visualize the world from another person's perspective.

IV- "Teaching earthly identity": understanding and spreading the conception that not only are we part of a society, but also, at the same time, that society is part of us by passing on to our values and a grounded worldview. In this context, the human being is recognized as multiple in a collective unit.

V- "Facing uncertainties": in all fields of knowledge, it is necessary to point out the emergence of the unexpected, understanding that scientific knowledge is not a producer of certainties. Uncertainty is essential because it directs the inquiring mind toward action in search of answers.

VI- "Teaching understanding": consolidating a planetary consciousness is necessary, recognizing that we live in a community with a common destiny. The idea of sustainability is reinforced to guide attitudes to promote a viable planetary legacy, thinking of the current and subsequent generations.

VII- "The ethics of humankind": development by every human being of ethics and personal autonomy, ensuring adequate social participation as an integral part of a community with a common destiny.

Morin (1998, p. 176, our translation) states that complexity cannot be conceived "as a recipe, as an answer, instead of considering it as a challenge and as motivation to think". We can consider, given this, that complex thinking is not a solution to the problems faced by humanity in the current context, especially in the field of Education, but a way to face current challenges, looking at them beyond the traditional Cartesian formula, which always tries to solve things through simplified cause-and-effect relationships. In this way, complexity theory is not a solution but a path built by walking - to paraphrase the Sevillian poet Antonio Machado, always remembered by Edgar Morin and other complexity thinkers.

Thus, thinking about the challenges of Education[1], which now merge with the challenges of teaching, we have outlined this academic production, aiming to weave together the theory of complexity with the learning of Physics. As outlined in the introduction, the point

[1] According to CAPES, Education and Teaching are two distinct evaluation areas, each with its own characteristics, defined by their respective area documents (38 and 46). Available at: https://www.gov.br/capes/pt-br/acesso-a-informacao/acoes-e-programas/avaliacao/sobre-a-avaliacao/areas-avaliacao/sobre-as-areas-de-avaliacao/sobre-as-areas-de-avaliacao. Acesso em: 10 Dec. 2022.

of departure and arrival are the theses and dissertations produced in the Brazilian post-graduation courses, which have already ventured along this path. The focus of the next section is how they were obtained and what these theses and dissertations are.

State of knowledge about Physics Teaching and complexity: methodological path

Studies dedicated to studying the productions already carried out on a particular subject can be recognized as being of the State of Knowledge type (FIORENTINI, 1994; ANDRÉ, 2000; FERREIRA, 2002). In this way, scientific redundancy is avoided by using the knowledge already addressed in diversified time frames to allow new directions and conclusions with clarity in the material constructed. The construction of a State of Knowledge becomes of great relevance in the academic environment, mainly due to the expansion of higher education and the consequent growth in the number of educational productions. Thus, the more research that is produced, the more difficult it is to keep up with the advance in the areas of knowledge; therefore, the systematization of these productions helps to understand how far progress has been made, its gaps, and its challenges.

Thus, this study also required a well-structured methodology and specific steps to obtain knowledge. However, aiming at the primary purpose that comprises the mapping of productions linked to Physics Teaching under the appropriation of Edgar Morin's Complexity theory, we established the organization of the methodological procedures and guidelines based on other previous works of the exact nature (MONTEIRO; FORTUNATO, 2019; FORTUNATO; TARDIN, 2020). We used, for this, the same procedures and sequence of actions: definition of the research problem, option for an appropriate database, delimitation of search criteria, selection based on the placed objectives, reading with annotated bibliographies and analysis, construction of the conclusive points with referrals.

The database used for this systematic survey was the Biblioteca Digital Brasileira de Teses e Dissertações[2] (Brazilian Digital Library of Theses and Dissertations) because it integrates information systems of academic works existing in the country, making available full-text theses and dissertations. We consulted the defined base in June 2022 to identify potential productions to contribute to the problem being investigated. After this first step, we followed the steps detailed below:

[2] Available at: https://bdtd.ibict.br/. Access: 10 Dec. 2022.

1. We searched for academic productions adopting as descriptors the terms "Morin" and "physics teaching", related to each other by the Boolean operator *AND*. Already in this first step, it was possible to verify the reduced number of works involving both listed descriptors since only 11 search results were found, characterized by eight dissertations and three theses, even considering all the academic production stored in the repository, i.e., without filters by date, areas or type of production.

2. As a continuity to organizing the cognizable material, after reading the titles of the works, we chose to identify those that deal with Physics Teaching. Thus, we selected seven productions that fit the guideline, six dissertations, and only one thesis. The other theses and dissertations were not considered because they focused on the curricular components of Physical Education and, in one case, Chemistry.

3. To complete the described methodological process, we read the abstracts and the introductory part of the selected works, seeking to confirm the approach to the subject of Physics teaching and to add verification of the presence of Morin's ideas about the complexity theory as a basis or with contributions. In this step, two studies were removed from the collection: one for not having any relation with the author in question and brought in the initial search because the author's last name contained a descriptor in the composition and the second one for having its main focus on an undergraduate course in Literature. Thus, at the end of this survey, we counted the contribution of academic productions: four dissertations (SILVEIRA, 2008; SANTOS, 2015; OLIVEIRA, 2016; CARMO, 2016) and one thesis (ARAÚJO, 2009).

In Table 01 below, it is possible to view more clearly and systematically the most relevant technical data of the research obtained in this mapping, allowing a deepening in the context of each of the studies and the quantitative analysis of the information available.

Chart 1 - Technical analysis of the dissertations and thesis on Physics Teaching that combine aspects of the complexity theory, according to Edgar Morin.

TITLE	YEAR	PROGRAM	INSTITUTION	AUTHOR	SUPERVISOR
Evolution of ideas of Physics for beginning Physics undergraduate students	2008	Professional Master's Degree in Science and Mathematics Teaching	Pontifical Catholic University of Minas Gerais	Tomás de Aquino Silveira	Prof. Dr. Yassuko Hosoume
Prototext, poetic narrative of science: a strategy for knowledge construction and knowledge reconnection in Physics teaching	2009	Doctoral degree in Education	The Federal University of Rio Grande do Norte	Valmir Henrique de Araujo	Prof. Dr. Maria da Conceição Xavier de Almeida
Approximations between Physics teaching and complexity in the construction of scientific knowledge in the light of a socio-environmental approach.	2015	Master's degree in Science of Science	Federal University of ABC	Fabiana Alves dos Santos	Prof. Dr. Maria Beatriz Fagundes
Study of a physics teaching proposal for the first year of high school inspired by Morin's complex thinking theory	2016	Professional Master's Degree in Educational Projects in Science	The University of São Paulo	Alvaro de Freitas Oliveira	Prof. Dr. Marco Aurélio Alvarenga Monteiro
The interdisciplinary relationship between Physics and Philosophy in the third year of high school in a public school in the city of Manaus	2016	Master's degree in Science of Science	Amazonas State University	Wanilce do Socorro Pimentel do Carmo	Prof. Dr. Josefina Barrera Kalhil

Source: Survey data

Initially, as already mentioned, we found that the number of available research studies that fit the defined parameters is small, which justifies the need for deepening and expanding the theme, relating the teaching of Physics with ideas from the complexity theory. Moving away from the rigid limits of specialization towards understanding the precepts of the complexity of the phenomena is a step of great relevance, which can help overcome the obstacles outlined in the previous section, which interfere in the educational, social, political, economic fields, etc.

Another important point to highlight is the year of publication of the papers, one from 2008, one from 2009, one from 2015, and two from 2016. This temporal distribution is quite uneven and recent because Edgar Morin is an author with a long and dense trajectory of works and publications that began in the 1950s. This observation allows us to infer that the relative presence of research involving Physics Teaching and the author in recent years is because Edgar

Morin's titles aimed directly at the area of education appeared in the late 1990s as a continuation of all the theoretical support consolidated in favor of a method of reconnection of the natural sciences, the human being, and life. The technological innovations at the end of the last century and the cultural and economic situation at the end of the Cold War brought the intensification of the globalization process. In addition to the more excellent circulation of people and consumer goods, the production and circulation of information have also increased, accentuating the presence of science on the social agenda and bringing out the need for new ways of interpretation and construction of knowledge, especially in the school context.

Following the mapping, when analyzing the origin of the research, we realize that it was conducted in distinct formative institutions: Pontifical Catholic University of Minas Gerais (PUCMG), Federal University of Rio Grande do Norte (UFRN), Federal University of ABC (UFABC), University of São Paulo (USP), and State University of Amazonas (UEA). In addition, we have two federal universities, two state universities, and one private institution (although it is philanthropic, confessional, and non-profit), ensuring the predominance of public and non-profit institutions involved with producing knowledge in the theme.

The Programs responsible for the selected papers were, in their totality, involved with Education and Teaching, mostly related to Science and Mathematics. Thus, we have two types of research coming from Master in Science Teaching programs, one from a Master in Science and Mathematics Teaching program, one from a Professional Master in Educational Projects in Science, and one study from a Doctoral program in Education. It was expected that the dissertations and thesis related to Physics Teaching to Edgar Morin's complexity theory would have been produced on programs about Education and Science Teaching.

Regarding the regional distribution of the analyzed works, 60% of the sample was produced in the Southeast region, where the approach to the theme was predominant. Beyond this region, we had one research project that originated in the Brazilian Northeast and one in the Northern region. Based on the regional distribution of the evaluated Graduate Programs in the area of Education by CAPES, the prevalence of institutions in the southeast region is confirmed, responsible for 35% of the Programs. In the area of Education evaluation, likewise, the number of programs in the southeast region is higher and corresponds to 38% of the total (BRASIL, 2020). However, taking the data presented as a subsidy, it is pertinent to mention the need to expand the visibility and scope of the relationship between complexity and Physics teaching since it brought scarce productions with greater representativeness in the geographical area where more Programs are available, proportionally.

After analyzing the dissertations and thesis and presenting a panorama of their more objective data, we will analyze each research more carefully to inventory its qualitative elements: objectives, methodology, data/subjects, and results. Ultimately, we aim to verify how all this relates to Physics teaching.

Complex thinking and Physics teaching: qualitative analysis of the studies

Table 2 - Qualitative analysis of dissertations and thesis on physics teaching that address aspects of complex thinking, part 1: general objectives, methodology, subjects, and data collection

Nº	GENERAL OBJECTIVE	METHODOLOGY	SUBJECTS	DATA COLLECTION
1	To evaluate the influence and capture the meaning of the subject Evolution of Ideas of Physics I on the students of the 1st period of the Undergraduate course at PUC-Minas.	Quantitative and qualitative case study.	Sixty-three students took this course in the 1st period from 2003 to 2007.	Open-ended questionnaire.
2	To present the notion of prototext as a complex system, as a strategy for constructing knowledge and reconnection in Physics teaching.	Bibliographic research.	None.	Bibliographic survey about the approximation between Physics and Literature, the method as a strategy (MORIN, 1998), the principle of complementarity (BOHR, 2000), and the conception of time (PRIGOGINE, 1991).
3	To reflect on the potential of teaching situations that can work on in Physics classes to construct a scientific culture focused on the valorization of complex education.	Qualitative case study with participant observation	27 students in the 2nd year of High School.	Audio recording, open-ended questionnaires, and verbal and written language productions in 20 classes.
4	To restructure the pedagogical practice in Physics Teaching for the first year of High School, respecting the official Curriculum of São Paulo State while seeking to contribute to developing students' complex thinking.	Quantitative and qualitative case study.	67 Science and Math teachers.	Presentation of the teaching proposal in the form of a didactic sequence and evaluation by teachers through questionnaires.
5	To analyze the conceptions of students and teachers about the interdisciplinary work of Physics and Philosophy.	Quantitative and qualitative case study.	Two 3rd year High School classes, two Physics teachers, and one Philosophy teacher.	Semi-structured interviews with teachers, observation of classes, and questionnaire analyzed by Likert scale initial and final with students.

Source: Survey data

Table 3 - Qualitative analysis of dissertations and thesis on physics teaching that address aspects of complex thinking, part 2: main results

Nº	GENERAL OBJECTIVE	MAIN RESULTS
1	To evaluate the influence and capture the meaning of the subject Evolution of Ideas of Physics I on the students of the 1st period of the Undergraduate course at PUC-Minas.	The students had little or no prior knowledge of the History of Science; the use of questionnaires throughout the course helped them to learn; the final evaluation using questions presented in the text was positive; the book and the workbook used, considered difficult by a portion of the students, played the role of balance disruptors; the use of video was a motivating factor for study; the course had a positive influence on the understanding of other subjects in the course; the course had a very positive general evaluation by the students and influenced them to continue their studies in the class.
2	To present the notion of prototext as a complex system, as a strategy for constructing knowledge and reconnection in Physics teaching.	The prototext consists of an organizing principle of knowledge as a complex system. This instrument is not defended as the only modality capable of giving life to concepts but as a possible strategy to guarantee the intelligibility of science using the imagination so abundantly made possible by literary creation. Not being a substitute for mathematical formalization, the prototext intends to be more appropriately a context where concepts, formulas, and measures gain flow, meaning, and harmony with the science learner.
3	To reflect on the potential of teaching situations that can be worked on in Physics classes to construct a scientific culture focused on the valorization of complex education.	It was identified that students began to articulate different areas of knowledge in constructing their arguments on environmental issues. Teaching proposals aimed at an education focused on complexity in science present a good result about overcoming the paradigm of fragmentation and disarticulation of knowledge.
4	To restructure the pedagogical practice in Physics Teaching for the first year of High School, respecting the official Curriculum of São Paulo State while seeking to contribute to developing students' complex thinking.	The teaching of the specific content of Physics is no longer the ultimate goal of the teaching work but a tool at the service of education for forming a critical, participative citizen, aware that his local decisions may have a global impact. The methodology's success is not in the proposed activities but depends on the teacher's sensitivity to identify at what level the knowledge of Morin has been developed so that it can be approached with greater complexity in the following proposals.
5	To analyze the conceptions of students and teachers about the interdisciplinary work of Physics and Philosophy.	Interdisciplinarity is superficial. The teachers bring interdisciplinarity to their classroom discourse, mediating content that includes both Philosophy and Physics because they understand that Philosophy is the basis of all sciences, however, it is evident that the teaching plan does not have it, although it is present in the National Curricular Parameters. Therefore, the such idea should be applied through another perspective, aiming at the student and teacher to consolidate teaching and learning in the core of reflection and criticality, involving them in the applicability of the pedagogical practice.

Source: Survey data

This qualitative analysis allowed us to establish some considerations and connections in the list. Methodologically, most of the research was characterized by the authors as being of the quantitative and qualitative case study type (SILVEIRA, 2008; OLIVEIRA, 2016; CARMO, 2016) for using diversified instruments and procedures to achieve the intended objectives, which required a look at statistical and interpretative data. We also have available a bibliographical type study (ARAÚJO, 2009) and one that prized the qualitative case study approach with participant observation (SANTOS, 2015), which was predominant in the collection and analysis of subjective data on human phenomena and behavior. This distribution is compatible with what is expected from this mapping, i.e., the establishment of relationships between physics teaching and complex thinking because, for effective results, it is valid to study the educational experiences and perceptions of students and teachers who make up the sample in a contextualized way with the theory, which brings multiple aspects related to each other and subject to a more interpretative analysis.

A relevant aspect of being dealt with is the subjects participating in the research. Three case study studies used high school students to compose the data (SANTOS, 2015; OLIVEIRA, 2016; CARMO, 2016). Only one research brought as contributors students from a Physics undergraduate course (SILVEIRA, 2008), however, because it is a first-semester sample of undergraduate students who have just graduated from high school, the audience described is very similar to the others. In these four works that brought the field research, the student's difficulty in learning Physics was mentioned, either due to the distance of concepts from reality resulting from the methodologies and educational strategies adopted, by the highly traditional and technicist approach, or even by the extensive application of formulas and calculations.

Another critical point refers to the context of the researchers who authored the dissertations and thesis since all of them are Physics teachers with experience in the educational field. Three authors mentioned having a direct relationship with the research environment, including teaching the subjects who contributed the information for analysis in the studies (SILVEIRA, 2008; SANTOS, 2015; OLIVEIRA, 2010). In one of the works, the researcher had already taught classes in the school adopted as the environment to be investigated, facilitating access to the groups and data needed (CARMO, 2016). Araújo (2009), in turn, is a Physics teacher and has already had the opportunity to apply the methodology he presents in his thesis, but this process is not described and is not his research focus. However, we can infer that, in all cases, the research originated from questions arising from the educational practice,

raising the degree of applicability of the results obtained and probably contributing to the authors' reflective practice and professional development.

Analyzing the objectives proposed by each of the research studies makes it possible to identify some similarities. Two productions follow different paths: the investigation built by Silveira (2008) aims primarily to understand the influences of the Physics Undergraduate course's discipline on students, and Araújo's (2009) work presents a pedagogical strategy as a complex system to enable the reconnection of knowledge. However, the dissertations by Santos (2015), Oliveira (2016), and Carmo (2016), in general, sought to reflect, identify and analyze teaching situations to contribute to a complex education, being important epistemological choices to foster the current reflections regarding Physics teaching and its effectiveness in the current reality. These discussions provide teachers and others involved in the area with diversified perspectives and possible adaptations in teaching and learning actions.

As for the results, there is no way to draw agreement because each work reached different conclusions from their distinct purposes. We saw Silveira (2008) verifying that his pedagogical work on the History of Science was well evaluated by his students, having qualified it as positive. Araújo (2009), in turn, presented a pedagogical tool for organizing complex thinking called "prototext" (a poetic narrative of science). In Santos' (2015) reflection, there was the verification that the idea of complexity inserted in training collaborates with overcoming the current paradigm of fragmentation of knowledge. Oliveira (2016), in turn, put the specific content of Physics in second place in his teaching practice, thinking first in the formation of critical thinking and citizenship. Finally, Carmo (2016) found that interdisciplinarity exists in the guiding teaching documents but not in the daily practice of teaching plans.

When revisiting the results, however, we find that complex thinking or complexity appears prominently, neither as a method nor as paradigmatic ground nor even as a proposal for reconnection of the seven pieces of knowledge. Instead, the results of the mapped dissertations and thesis lead us to recognize a fundamental gap in Physics Teaching research: the presence of complex thinking as a guide, (re)organizer of knowledge, and as a way to build knowledge.

Final considerations

> [...] science is at the core of society and, although quite distinct from that society, it is inseparable from it, which means that all sciences, including the physical and biological, are social. But we must not forget that everything that is anthropological has an origin, a rooting, and a biophysical component (MORIN, 1998, p. 20, emphasis added, our translation).

We begin this article with the idea of trying to understand the relationship between Edgar Morin's complex thinking and the area of Physics Teaching. Is there a relationship? Is this area developing, seeking better and better methods for Physics to be taught and learned in school? These doubts produced a state of knowledge, mapping national theses and dissertations.

We started the article by recovering the rudiments of complex thinking, as conceived by Edgar Morin and recorded in his best-known works in the field of education. We have seen his seven knowledge needs for the education of the future, the principles of complexity, and the reconnection of knowledge. From there, we demonstrated how the research that led to the systematization of the state of knowledge was built, having mapped four dissertations and one thesis.

The number of mapped works was very small, insufficient to establish recurrences that would guarantee to solidify a state of knowledge. Except, of course, all the research authors are Physics teachers, having used their everyday life as a place for research. These teacher-researchers have realized that the fragmentation of knowledge into closed disciplines leads to a distortion of phenomena. It is as stated in the epigraph of the final considerations: Physics is a science that is also social, therefore, its postulates, its formulas, and its worldviews are not isolated from society.

Thus, we can see a principle starting to take root in Physics teaching from the school ground. This is important because often, things are imposed, whether curricula, exams, training guidelines (initial and continuing education), class hours, number of students, systems to be used, etc. Thus, by verifying that this correlation between complex thinking and Physics teaching, although incipient, is starting to immerse itself in the school, we can see a possible beginning of a transformation.

So much is said about education for critical and, citizenship education and contextualized teaching, but very little is effectively done so that this leaves the discourse and becomes a practice in schools. However, when we meet Physics teachers researching ways to complexify their training, we realize that there are movements underway in schools to open up the fragmented schooling in disciplines closed in their fields of knowledge to the complex.

Finally, we declare that, although the mapping revealed that there are very few works at the interface between complexity and Physics teaching, this movement also brings back the enchantment for education and the hope that we can, yes, be more complex in school, as we are in the world.

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CRediT Author Statement

Acknowledgments: Not applicable.

Funding: Not applicable.

Conflicts of interest: Not applicable.

Ethical approval: The work respected ethics during the research, but did not go through an ethics committee.

Data and material availability: Yes, the data and materials are available in the Brazilian Digital Library of Theses and Dissertations.

Author's contributions: All authors participated in the data collection, writing and reviewing of the article.

Processamento e edição: Editora Ibero-Americana de Educação.
Correção, formatação, normalização e tradução.