



Environmental Education and Complexity

A Study Based on Brazilian Theses and Dissertations

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Abstract

The purpose of this study is to identify and analyze meanings that the term *complexity* assumes in Brazilian theses and dissertations in the field of environmental education, especially when addressing socio-environmental issues. The studies were selected from the database Theses and Dissertations of EArte (<http://earte.net/>), which is a repository for Brazilian theses and dissertations in the field of environmental education. Twenty theses and dissertations were selected to compose the documental *corpus* of this investigation. For the investigation, content analysis was used. Three a priori categories were defined to analyze the meanings of Complexity: (1) complex thinking: organized from Morin's ideas of Dialogical Principle, Organizational Recursion Principle, Holographic Principle, and *Scienza Nuova*; (2) complex systems: organized from uncertainty, dynamics, and open systems groupings; and (3) complexification organized from the environmental complexity grouping. The complex thinking category was the most frequent in the analyses, identified in fifteen of the twenty theses and dissertations. In twelve of the twenty dissertations, the category of complex systems was identified, while in four of the twenty, the category complexification was referenced. These studies show a greater inclination towards the ideas of Edgar Morin and Enrique Leff.

1 Introduction

From the second half of the twentieth century onwards, humanity began to experience important environmental issues more often, many of which were marked by an increasing number of human victims in so-called socio-environmental issues. The intensity and the extent of these problems mark the present moment in the history of humanity, such that

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it is possible to say that the humankind experiences an environmental crisis characterized by the entire context that surrounds its causes, effects, origins and attempts to reverse this situation.

Sociologist Leff and Vieira (2001), one of the defenders of the existence of an environmental crisis, indicates that this type of crisis questions the knowledge that guides us in the construction and organization of human society. For the author, the environmental crisis forces human beings to face problems that cannot be properly understood from the already established paradigms of classical sciences. For Leff and Vieira (2001), understanding the environmental crisis requires studies that understand the environment as a complex system involving the interrelation of living and non-living entities.

The idea of complex systems (sometimes referred to as the field of complexity), according to Mitchell (2009), can be understood in a broad sense, as a system which allows networks of components without any central control or any simple rules of operation. This kind of system also enables complex collective behavior, in addition to processing different information among its components and adaptation by learning or evolution. The author also proposes an alternative definition for complex systems as “a system that exhibits non-trivial emergent and self-organizing behaviours” (p.13). In light of this, it is possible to say that association between socio-environmental issues and complex systems seems to be a way to address this kind of problem.

Jacobson and Wilensky (2006) indicate that complex systems is a multidisciplinary field of science that studies several types of complex systems of the real world, such as events and actions that have multiple causes and consequences. Based on this definition of complex systems, system behaviors that have been systematically ignored or oversimplified by classical sciences are now included as basic elements and by many aspects observed in the world. Associated with those studies are a series of conceptual perspectives (principles) such as the multi-scale hierarchical organization, emerging patterns, dynamic attractors, and non-scale analysis networks. The authors mention some specific scientific methods related to study of complex systems, such as computational modeling and network analysis. Each field of science has its own concepts and methods associated with what scientists call complex systems.

For Mitchell (2009), complex systems is an interdisciplinary field of research, which basically seeks to explain the organization of entities and also how large the organization is, the use of patterns, the information and learning process, without a central controller. There are different complex systems in nature. The author cites some examples as “insect colonies, immune systems, brains, and economies, have much in common” (p. 4).

It is important to highlight that scientific views on complex systems primarily come from research in the physical sciences, mathematics, and computer science (Jacobson et al., 2019). In the field of hard sciences that term is frequently associated with events and actions that have multiple causes and consequences (Jacobson & Wilensky, 2006). Certainly, some concepts of complex systems undergo changes when they are transported from one field of knowledge to another. This transition of concepts from one field of knowledge to another is certainly not without criticism. Nonetheless, the idea of events with multiple causes and consequences seems to be central in order to generally understand socio-environmental issues. One example is that the consequences of our consumption choices have to be described in terms of environmental issues, as well as being framed in societal terms (Benninghaus et al., 2019).

Another relevant aspect of the discussion involving socio-environmental issues lies in the fact that, regardless of how they are understood, they have mobilized different sectors of society in an attempt to mitigate their effects. In this context, the educational process

itself presents a possibility for transformation of this picture; that is, the educational process is often understood as a social action that induces the transformation of reality (Carvalho, 2006).

It is important to highlight that it is possible and desirable for educational discussion involving socio-environmental issues to be articulated with ideas of complex systems. Jacobson and Wilensky (2006) highlight the importance of complex systems for the educational process:

The conceptual basis of complex systems ideas reflects a dramatic change in perspective that is increasingly important for students to develop as it opens up new intellectual horizons, new explanatory frameworks, and new methodologies that are becoming of central importance in scientific and professional environments (p. 12)

In fact, some ideas related to complex systems have been gaining space in the educational realm, including in the academic discussion on Brazilian education. Jacobson et al. (2019), for example, emphasize that the appropriation of ideas related to complex systems has caused important innovations in the field of education, both from the point of view of pedagogical processes as well as from the perspective of building a greater body of investigation in this field of knowledge.

Among these studies in the field of education, those related to science education are more common. The work of Levrini et al. (2013), for example, deals with an approach to thermodynamics from a complex systems perspective. The authors highlight that aspects of thermodynamics are essential for understanding environmental issues, and in this sense, it can be a way to bring Physics to environmental education through the approach of complex systems. The work of Dauer and Dauer (2016) highlights the importance of the complexity approach for teaching biology. In the words of the authors “the intricacies of biological systems are important for students to understand for medical, environmental, and social health” (p. 1). Levy and Wilensky (2009), consider addressing complex systems in chemistry classes for a broad understanding of the meaning of molecular interactions. There is some indication in these works about the possibility of building bridges between the fields of science education and environmental education from the approach of ideas related to complex systems. Mambrey et al. (2020) point out that ecosystems are complex systems and thus involve the interrelation of entities in a given area. According to the authors, there are two main types of interrelation in ecosystems: direct and indirect. Direct interrelations are linked to cause and effect relations, such as predator–prey relationships, while indirect interrelations encompass all the effects that cannot be explained by direct effects, to the effects that “cannot be assigned inevitably to a directly related population but may in fact be mediated by multiple and/or distant populations. These indirect effects play a major role in understanding and modelling ecosystems” (p. 6).

There are many good examples of studies that deal with complexity in the area of science education. Nonetheless, there are also many from the environmental education field. The research from Guimarães (2007) is a suitable example of a study that links environmental education and complex systems. The author emphasizes that environmental education allows for very promising relations between human beings and the environment in which they live, enabling them to be better understood, as the environment begins to be understood and recognized as a complex system.

It is worth highlighting that some studies in the environmental educational field refer to terms such as complex thinking. Benninghaus et al. (2019) point out that most of society recognizes that environmental issues are one of the most important problems for our time. They also highlight the relevance of treating environmental issues as complex phenomena,

in particular because these problems are accompanied by a decrease in predictability and an increase in uncertainty. In this perspective, the authors suggest that these problems should be approached from the model of complex thinking, since these are interdisciplinary in nature and cannot be solved within the scope of any singular discipline. Because of that scenario, terms such as complex thinking were considered in this research as a broad sense of the field of complexity.

It is also relevant to note some educational studies attempt to relate socio-environmental issues to science education through discussion and examination of certain ideas of complex systems. Particularly focusing on Brazil, environmental education has historically been introduced through the disciplines of biological sciences, and science, for students aged 15 to 17 years, and 11 to 14 years, respectively. In this specific scenario, which involves the educational process, attention is drawn to the constitution and consolidation of the field of environmental education. In Brazil, for example, the field of environmental education has extensive and qualified scientific and academic production since the late 1970s. This production can be seen in articles in periodicals, theses, dissertations, books, and educational materials of all kinds.

At this moment, a number of important studies are being developed in the field of environmental education in Brazil seeking to better understand the meaning of the production in this field over almost fifty years. There are questions over how much is actually known about the knowledge generated, especially related to the dissemination of research results. Researchers such as Reigota (2007) and Fracalanza et al. (2013) have elaborated studies to map and analyze the production in the area of environmental education. Overall, this research shows that production in this area has increased, in particular, since the 2000s.

Similar studies have been conducted outside of Brazil. For example, Arboleda and Páramo (2014) indicate a growth in the research area in Latin American, in terms of academic production, from a review of environmental education works. In the northern hemisphere similar studies were conducted by Hart and Nolan (1999), Marcinkowski, (2013) and Payne (2009). For these authors from the northern hemisphere, there is a strong indication of the existence of a sustainable growth of scientific production in the field of environmental education in English-speaking countries.

In Brazil, one academic project aims to map and organize the production of theses and dissertations in the area of environmental education. The project is being developed by four Brazilian public universities: Universidade Estadual Paulista (UNESP), Universidade de Campinas (UNICAMP), Universidade de São Paulo (USP), and Universidade Federal de São Carlos (UFSCar). The project is called EArte (Estado da Arte da Pesquisa em Educação Ambiental) and currently has a collection of 4,205¹ theses and dissertations. EArte has made it possible to broaden and deepen studies aimed at understanding the knowledge generation in the environmental education field.

Based on these considerations, an investigation was carried out with the aim of contributing to the efforts of Brazilian researchers who seek to map and analyze knowledge generation in the field of environmental education that is disseminated in the form of theses and dissertations (Souza, 2012; Magacho, 2017; Dias, 2015; Palmieri, 2011; Souza, 2010; Bitar, 2010). Within this scope, this investigation focused on Brazilian theses and dissertations in the EArte database that are related to the field of science education and involve discussion on complex systems in a broad sense. From these notes, the question is put forth: what aspects of complexity are addressed and redefined by the area of research in environmental education in relation to the area of science education?

¹ Item read out in May 2019.

Through the search for mechanisms which aid in better understanding of these questions, it is understood that theses and dissertations comprise an important source of documents in the area, given the significant amount of these studies in Brazil. Moreover, according to Romanowski and Ens (2006), such academic endeavors are trustworthy because they have been submitted to peer review for approval. According to Lubisco and Vieira (2008), theses and dissertations are characterized as primary sources of information, since they are produced directly by the authors. In light of this, a study on this material is relevant.

1.1 Complexity in a Broad Sense in the Context of Brazilian Education Through the Perspectives of Edgar Morin, Enrique Leff, and Ilya Prigogine

There are select references in the Brazilian educational context that reference the term complex system, complexification, and complex thinking. Moreover, it is important to highlight that, according to Mitchell (2009), there is no single science of complexity, just as no single theory on complexity exists yet. These terms can be found in a wide variety of approaches and perspectives in the same way that Schlindwein and Ison (2004) present this discussion in their paper. In an attempt to understand this diversity, the authors systematized information into two major groups: descriptive and perceived complexity.

Broadly we can say that in some explanations complexity has been understood as an intrinsic property of a certain kind of system, or as occurring in a certain kind of natural and social phenomena. The kind of complexity emerging from this understanding can be called ‘descriptive complexity’. [...] In other explanations complexity has been understood as the result of a distinction or resulting from a particular perception of a situation (of complexity) made by an observer, what can be denominated as ‘perceived complexity’ (p. 2).

Szekely and Mason (2018) indicated that more than 31 definitions of complexity were found in one specific study. The authors also mention three main schools of thought within the field complexity: “a reductionist complexity science, which adjusts available methodological tools to better respond to the principles of complexity; a soft complexity science, used by social scientists to change the patterns of understanding of social policy; and complexity thinking, which spans both” (p. 6).

Within the scope of the Brazilian education system, there is a broad perspective of using the idea of complexity and complex systems. However, the most common references are the works produced by Edgar Morin, Enrique Leff, and Ilya Prigogine. Based on the central ideas of these authors, a priori categories were developed to assist in the data analysis process. It is important to be aware that some ideas of complexity or complex systems can contain significant changes when comparisons are made between one area of knowledge and another.

Edgar Morin associates the idea of complex thinking with his analysis of specific problems in the field of social sciences (Santos & Hammerschmidt, 2012; Alves & Seminotti, 2006; Caluzi & Rosella, 2003; Curvello & Skroferneker, 2008; Silva, 2011; Morin, 1992; Cruz et al., 2006; Schlindwein & Ison, 2004; Alhadef-Jones, 2010). Mentions to Morin and Lisboa (2015) are frequently found in works related to the Brazilian education field. Mentions to Morin’s three principles of complexity are also common: Dialogical Principle; Principle of Organizational Recursion; and Holographic Principle.

Szekely and Mason (2018) mention that Morin’s works can be useful when facing the most important challenges of our time. The authors indicate that (...) Morin has argued

that the principles that help to understand natural phenomena are also useful for understanding how the anthropo-social world operates, and that the patterns that govern our understanding of those principles have been and will remain crucial to the way we face the challenge of sustainable development (p. 6).

In the referenced study, research was conducted on the category named complex thinking based in Morin and Lisboa's ideas (2015). In that work, the author related complex thinking with three principles:

- 1) Dialogical principle: the idea that certain concepts are necessary to each other for their own understanding. Thus, it can be said that they are interdependent.
- 2) Principle of organizational recursion: it relates to the idea of "product and producer", way, in the same way that, for example, the subject acts on the object and modifies it, the object it also acts on the subject by modifying it, that is, both are mutually modifying.
- 3) Holographic principle: the idea that the whole is more than the sum of its parts, not only the part is in the whole, but the whole is in the part (p. 74).

In addition to Morin's work, in the specific context of environmental education in Brazil, there are also many mentions to Leff's work. Leff proposed the wide use of complex systems ideas for a better understanding of socio-environmental issues (Cembranel, 2015; Loureiro, 2005; Cabral Balim et al., 2014; Pitanga, 2015; Floriani, 2001). According to Leff and Vieira (2001), the understanding of environmental phenomena requires taking into account the complexities that are inherent in them, this form of understanding nature leads the individual to reidentify as part of this environment. In this perspective, according to Leff and Vieira (2001), the understanding of socio-environmental issues should follow different ways of complexifying reality. In some studies in the field of environmental education, one can see arguments that try to connect complex systems and uncertainties and risks. In this case socio-environmental issues are characterized by its non-linearity, dynamics, instability, and unpredictability (Reis et al., 2015).

The idea of complexification is central to Leff's work. That idea comes about from a particular perception of a situation (of complexity) the idea of making something complex, or that is, start seeing it in a complex way. The complexification process consists in perceiving the intertwining of physical, biological, and cultural orders. Understand that there is a process of hybridization between the economy, technology, life, and the symbolic realms. Recognize that knowledge about reality must take into account the different processes that lead to dialogue between different forms of knowledge and the hybridization between science and technology. Finally, the interpretation of the environment as a heterogeneous and conflicting field, in which knowledge and different interests exist. Leff and Vieira (2001) points out that, in order to understand problems related to environmental issues, an overdetermination or articulation of the effects of the processes of the objects of these sciences is needed. Thus, it is not possible to understand the relations between society-nature and their respective problems from a segmented view. For the author, environmental issues alone, in a broader sense, cannot be understood from a single method, based on absolute rigor, mathematical, quantified, and empirical. It is necessary to understand them from different and complex articulated aspects, as they are complex in nature.

In this research, the category named complexification based on Leff and Vieira's ideas (2001) was elaborated. In that study, the author described complexification in seven ways: (a) the complexification of the real; (b) the complexification of knowledge; (c) the complexification of production; (d) the complexification of time; (e) the complexification of identities; (f) the complexification of interpretations; (g) the complexification of being. The different complexification pathways stand out in the construction of environmental

complexity, which is based on the construction of new knowledge and a new rationality, thus recognizing new forms of knowledge and apprehension of the world.

Finally, there are many references in the Brazilian educational context to the works of Ilya Prigogine (Almeida, 2004; Levy & Santo Oliveira, 2007; Neutzling & Pedrozo, 2015; Caraça, 2000; Massoni, 2008). In the field of science education, Prigogine (2011) and Prigogine and Stengers (1992) are frequently found and cited. There are some considerations about out of balance systems and irreversible situations. Many of these works characterize chaotic behavior of specific systems, especially in cases involving thermodynamic subjects.

In this research, the category named complex systems was elaborated, based on the work of Prigogine (2011). This category is related to the ideas of uncertainty, dynamics, and open systems. Prigogine (2011) and Prigogine and Stengers (1992) highlight that complex systems, in summary, study physical phenomenon that are out of balance. The authors explain what irreversible physical phenomenon is, highlighting the fact that these phenomena are not exceptions in nature. They emphasize that it is impossible to predict time evolution in complex systems (indeterministic phenomenon).

Three concepts are highlighted in that category. First, the idea of uncertainty refers to complex systems carrying with them some level of inherent unpredictability (Prigogine, 2011). Second, the concept of dynamics, which represents those nuclei of meaning, places emphasis on the dynamic processes when referring to complex systems. For Prigogine (2011), dynamic systems are those in which one finds instabilities and bifurcations at all levels, systems that are far out of balance. Finally, the author presents the idea of an open system, which can be understood as the one that groups the nuclei of meaning that deals with non-stable systems; that is, out of balance. Open systems can be understood as thermodynamic concepts and the ideas of balance and non-balance can be explored.

Specifically in relation to the field of environmental education, the term complex systems has been used in different ways and to consider different fields of knowledge. However, just as in the broad field of education, there are a large number of references to the works of Leff, Morin and Prigogine.

2 Methodology

The empirical study is qualitative in nature and involves document analysis. According to Gil (2008), this type of research is characterized by dealing with materials that have not received analytical treatment, or that can be redesigned according to their objectives. In the present study, an investigation is put forth on the documental *corpus* of Brazilian theses and dissertations from the field of environmental education, which possess some connection with the field of science education and that deal with complexities in a central way in their discussion.

Electronic information of theses and dissertations was consulted for the constitution of the documental *corpus* of this research (www.earte.net/teses/). The EArte database contains information about theses and dissertations, including abstracts. There is no file in this electronic database containing the complete manuscript of the thesis or dissertation.

The site search tool was used to select the studies. The term “complex” was used in all searches, and 328 studies were identified, from those containing the expression “complex thinking” to those containing the idea of “complex systems.”

The next step was to read all 328 abstracts to define the documental *corpus*, guided by three criteria: inclusion, exclusion, and doubt. These criteria were developed in order to

attend the aims proposed for the process of conducting this research, which consists in the search for meanings of varying terms of complexity in theses and dissertations in environmental education, having some connection with the science education field.

- Inclusion criteria—abstracts in which the idea of complex systems is presented in the perspective of articulating the science education field and environmental education field.
- Exclusion criteria—abstracts that do not present the idea of complex systems nor articulations between science education and environmental education.
- Doubt criterion—abstracts that present the term complexity but do not make it clear if the discussion of this theme is central in the work.

From reading the abstracts, the studies were divided into three groups:

(1) 36 abstracts that clearly indicate they should compose the documental *corpus* for analysis; (2) 262 abstracts that clearly indicate for theses and dissertations that do not compose the documental *corpus*; (3) 30 abstracts which do not make it possible to decide whether their related theses and dissertations constitute the documental *corpus*.

The decision was made to look for the full text of each of the 30 dissertations and theses in the doubt group to decide if they met the criteria set forth in this investigation. From the full thesis or dissertation, it was possible to verify if they presented at least one chapter in which the idea of a complex system was central to the text. After this activity, none of the 30 studies would be included in the documental *corpus*.

The second step in defining the documental *corpus* involved searching for the complete works of the 36 theses and dissertations initially selected from the abstracts. To do this, the electronic files of the complete manuscript were located using internet search engines. At this stage, 23 electronic files containing complete works were found in their respective institutional repositories.

After reading the 23 studies in their entirety, it was decided that 6 would be excluded because they do not present an organized discussion on complex systems. The remaining 17 would be part of the definitive documental *corpus*.

There were still 13 complete theses and dissertations left. To address these works, the authors were contacted. Ten of them via email, and three via the Lattes² platform contact tool. Of the ten authors contacted via email, four submitted the electronic file of the complete work. After reading them, it was decided that two would be part of the definitive documental *corpus* of the investigation, while the other two would be discarded. Of the three authors that were contacted directly via the Lattes platform, two submitted their complete studies. However, after reviewing them, they were excluded. The documental research *corpus*, at this time, was comprised of 19 complete works. Ten works had been excluded from the definitive documental *corpus*.

Finally, a second attempt was made with the six authors who did not reply to the email message. To do this, the contact tool on the Lattes platform was used. One author sent the electronic file of the complete work. After reading the study, it was determined that it would also be part of the definitive documental *corpus* of the investigation. At

² The Lattes Platform is a virtual curriculum system created and maintained by CAPES (Coordination for the Improvement of Higher Education Personnel), which integrates the curriculum databases, research groups, and institutions into a single information system for science and technology areas, acting in Brazil (Lattes Platform, 2019).

this point, a collection of 20 theses and dissertations formed the documental research corpus. Ten works had been excluded.

The six studies that could not be found were finally excluded from the definitive documental *corpus*. That is, 16 works were excluded and 20 composed the documental *corpus* of the research. Fourteen were the fruit of master's degree studies (identified by the letter "D" followed by a number) and six came from doctoral work (named by the letter "T" followed by a number). Table 1 presents all the studies that were selected for analysis and are organized chronologically. Additionally, identifiers were assigned in the first stage of defining the corpus of this investigation, when 36 studies were included. So, it is possible to realize that the numbering of identifiers does not exactly follow an order.

The analytical process started with the reading of each complete study. From this reading, excerpts were identified in the works that demonstrate ideas related to complex systems. Some terms related to complexity and complex thinking were found. These excerpts contain important information about how Brazilian theses and dissertations present ideas related to the idea of complexity in a broad sense.

These excerpts were collected and organized into classes of categories and subcategories, as suggested by Bardin (1979). The categories were defined based on the a priori bibliographic study adopted for this research. According to Bardin (1979), this analytical process is named content analysis and:

It represents a set of communication analysis techniques that aim to obtain, by means of systematic and objective procedures, the description of the message, indicator (quantitative or not) contents that allow the inference of knowledge regarding the conditions of production and reception of these messages (page 42).

Some findings are related to bibliographic revision made in this research. Other findings that did not fit into a priori categories were classified in new categories. The categories for this analysis are: "Complex thinking," "Complex Systems," and "Complexification." The constitution of the categories followed the strategy of locating, accounting, and systematizing the nuclei of meaning in groups constructed by similarity of meanings.

The category of complex thinking refers to the idea presented by Morin and Lisboa (2015). Particularly in this category excerpts were identified in the theses and dissertations that refer to the idea of building a new way of thinking in relation to environmental issues. For this, four groups were elaborated, which are: Morin's three principles—Dialogical, Organizational Recursion, and Holographic—and also the idea defined by him as *Scienza Nuova*.

The idea of complex systems was used based on the work of Prigogine (2011). In this category, excerpts were organized related to environmental issues that associated with ideas of complex systems. The groupings elaborated in this category were: uncertainty, dynamics, and open systems. Regarding the complexification category, the idea that through this topic, one can understand socio-environmental issues was identified in some excerpts taken from the theses and dissertations. For this category, a grouping was created, which is Leff's idea of environmental complexity.

2.1 Considerations About the Meanings of Complexity Presented by Morin, Leff, and Prigogine in Brazilian Theses and Dissertations

The data analysis process of this investigation was based on three categories given a priori: "Complex thinking," "Complex systems," and "Complexification." From that decision, the information found in the theses and dissertations were systematized.

Table 1 Information on the theses (T) and dissertations (D) submitted for the analysis

Title	Identifier	Author	Year
Natural Earth ecosystems as environments for activities of science teaching	D19	Tatiana Seniciato	2002
The dynamics of a natural sciences museum: the paradigmatic transformation of the Augusto Ruschi Zoobotanical Museum	D2	Flavia Biondo da Silva	2005
The complex paradigm: energy and education	D6	Douglas Ricardo Slaughtner Nyimi	2006
A complex base ecology	T3	Wylllys Abel Farkatt Tabosa	2007
Elements for thematic approach: the question of water and its complexity	D8	Giselle Watanabe Caramello	2008
Weaving connections between a formative trajectory of biology teachers and a teaching practice based on environmental education	D14	Mônica Lopes Fofena de Araújo	2008
Analysis of the contributions of educating through research in the study of energy sources	D26	Rosangela Ferreira Prestes	2008
Biocity: a project proposal in environmental education that enables dialogue between high school subjects	D28	Claudine de Andrade Silvestre	2008
The practice of transversality in teacher education: reflexes in basic education	D1	Fabiane de Matos Araújo	2009
Environmental physics and theory of complexity: possibilities of teaching in basic education	D3	Miguel Jorge Neto	2009
Environmental knowledge in the training of biology teacher	T2	Simone Sendin Moreira Guimarães	2009
Informatics in education and the teaching of natural sciences: contributions to environmental education in the amazon context	D17	Rosa Eulália Vital da Silva	2009
Environmental education in science education: training, practice and transversality	D4	Tatyanna de Melo Afonso	2011
Natural dynamics and teaching chemistry to adult education: knowledge and practices of curriculum innovation	D18	Silvana Maria Correa Zanini	2011
Environmental education work projects: a transdisciplinary alternative to teaching practice	D5	AdeImo Fernandes de Araújo	2011
Aspects of complexity: contributions of physics to understand the environmental theme	T1	Giselle Watanabe Caramello	2012
Perspectives of the holistic transdisciplinary vision and its contributions to the construction of an ecological society: the case of the Ecovillage Terra Una, Liberdade—MG	D12	Kelly Daiane Savariz Bölla	2012
Environmental education as a discipline in the training of biologists: a case study at the Federal University of Uberlândia	T4	Melchior Jose Tavares Junior	2012
Environmental knowledge: bridges of convergence that enacts in the living spaces of teacher training	T5	Robledo Lima Gil	2012
The ant and the cicada: environmental education and science teaching in public schools in Brasília—Distrito Federal	T6	Zara Faria Sobrinha Guimarães	2012

Table 2 presents the information regarding the constitution of complex thinking category.

In the construction of the Dialogical Principle grouping, the fact was considered that, in some theses and dissertations, there are nuclei of meaning in which the idea of dialogicity is presented as an underlying concept in the articulation of different ideas aimed at understanding and/or explaining socio-environmental issues. Table 2 presents an excerpt taken from D12 to exemplify this grouping.

Edgar Morin's texts are presented as one of the main references for those authors who defend changes in the way of thinking about complex contemporary problems, especially those related to socio-environmental topics. In this sense, the idea of the Dialogic Principle stands out, especially when the authors emphasize that the current paradigm in the construction of scientific knowledge fragments reality and fails to consider many fundamental aspects for a broader understanding of complex phenomena. In light of this, critical attention is also drawn to the predominance of a hyper-specialization of knowledge.

The second grouping, the Principle of Organizational Recursion, was organized from nuclei of meaning that explain the idea that, while human beings act in the environment, it also acts on them, thus introducing a complexity to understand socio-environmental issues. Three of the twenty analyzed studies explain this idea in their texts. About the excerpt extracted from T5 used in Table 2 to exemplify this grouping, it is worth emphasizing that, for the author, the individual influences the collective, as well as the collective influences the individual in a mutual relationship. This idea of mutual influences between collective and individual leads us to the idea of product and producer presented by Morin and Lisboa's Principle of Organizational Recursion (2015).

In other studies, excerpts were identified in which the authors articulate the discussion of socio-environmental issues with the Principle of Organizational Recursion. This is related to the idea that in the sense that the same way individuals have an effect on the world, it also affects individuals. In these studies, it is possible to recognize excerpts in which the authors argue that it is not possible to isolate a complex phenomenon to study it. The object under study interferes with the subject just as the subject interferes with it in order to understand it. In the third grouping, the Holographic Principle, the nuclei of meaning that highlight the idea of part and all as inseparable for understanding socio-environmental issues are systematized. Six of the twenty works that make up the documentary *corpus* present this idea in their texts for the discussion of socio-environmental issues.

Regarding the excerpt presented in Table 2 as an example of this grouping, extracted from D6, it can be said that for the author, reality itself, and thus also the socio-environmental issues, are presented in such a way that the parts have aspects of the totality because they are complex. This way of thinking about the complexity of nature's phenomena articulates with Morin and Lisboa's ideas (2015), especially his considerations about the Holographic Principle.

In other studies, excerpts were identified in which the importance of considering these phenomena is emphasized, rather than highlighting their fragments exclusively. The importance of treating complex problems by disassociating them from their parts is highlighted, given that fragmentation (the reduction of these phenomena to their parts) cannot explain them in their entirety, since the part is in the whole and the whole is in the part.

Other authors highlight the importance of understanding the phenomena from the idea of part and whole. In these studies, it has also been argued that a broad understanding

Table 2 Complex thinking when referring to socio-environmental issues

Groupings	Theses and dissertations	Extracts
Dialogical Principle		In this way, the case study of an ecovillage is important in demonstrating that a new world is possible, with a lifestyle that primarily aims at preserving life in its complexity, understanding the interrelationship between everything existing and that all beings who share existence with humans on Earth have their intrinsic value and their role in the evolutionary process of life (D12, p.19)
Principle of Organizational Recursion	T3, D12, T5	Within this perspective, there is no way to dissociate the human being from his autonomy (individuality), life in society (collectivity) and also belonging to its species in the world and with the world (T5, page 100)
Holographic Principle	D1, D2, D5, D6, D12, D19	The complex paradigm considers reality as essentially integrated, irreducible and where the parts themselves have aspects of complexity (entirety) (D6, page 24)
<i>Scienza Nuova</i>	D1, T1, T2	In this sense, it is a fact that we are experiencing a moment of paradigmatic ruptures, the old paradigm of modernity begins to ruin and, in its place, a new paradigm has been built for some time now, which has been trying to rescue an integrated cosmos to another level of complexity, which has been fighting the amputation of the faculties of perception, and is therefore viewed as a crisis of the subject, a subject who neither knew nor recognized the fullness and meaning of life (D1, page 34)

of nature goes through the perspective of understanding the inseparable idea of part and whole presented in some of Morin's ideas on complexity.

In the grouping entitled *Scienza Nuova*, nuclei of meaning were identified in the theses and dissertations in which there are arguments in favor of changes in the production of knowledge that enable the understanding of complex socio-environmental issues. Three papers in the documental *corpus* present this type of discussion. Regarding the excerpt from D1 to exemplify this grouping, presented in Table 2, the idea posited by the author on "paradigmatic ruptures" was highlighted. This, in fact, implies an idea of change in the concept of science. In this case, the author states that there is a new paradigm emerging and that it takes into account different aspects of a science based on complexity.

In two other studies, it was also possible to identify excerpts in which ideas are presented that defend changes in the process of construction of scientific knowledge. In them, complexity presents itself as a new scientific action, which takes into account previously ignored situations and presents the perspective of a new construction of thought itself, thus articulating the idea presented by Morin and Lisboa (2015), as *Scienza Nuova*.

Another category used to analyze data from this research is called "Complex Systems" and it was comprised of three groupings: (1) uncertainty, (2) dynamics, and (3) open systems.

Table 3 presents the systematized information regarding the Complex Systems category. In the grouping of Uncertainties, excerpts from the theses and dissertations were organized which have considerations on the idea of unpredictability and disorder, both associated with the idea of uncertainty inherent to the process of understanding socio-environmental issues. Five of the twenty theses and dissertations analyzed presented this idea in their discussions. Regarding the excerpt from D1 as an example of this grouping, presented in Table 3, one can see an argument that defends the idea that complexity is intertwined with considerations about the uncertainties present in reality. This articulates with the idea of uncertainty promoted by Prigogine (2011) in his book "The End of Certainty." They were also identified in other studies in which socio-environmental issues are related to the idea of uncertainties. There are excerpts that discuss the nature of socio-environmental issues from the ideas of unpredictability and uncertainty. Regarding the dynamic grouping, excerpts from theses and dissertations were identified that present the idea of instability in relation to the discussion of socio-environmental issues. Four of the twenty works that make up the documental *corpus* present excerpts with this discussion. Considering the excerpts presented in Table 3, extracted from T2, it can be highlighted that the author posits that socio-environmental issues generate instability in the environment. Thus, the science of complexity presents itself as an adequate way to understand this reality, still guided by the dynamics of Open Systems (Prigogine, 2011).

There are more studies also related to the idea of dynamic systems to address different aspects of socio-environmental issues. For example, in T1, there is an explanation about the environmental problem of the scarcity of drinking water that occurs in various parts of the world. The author mentions the dynamics of climate phenomena and their articulations with different ecosystems. In this sense, the atmosphere-biosphere interaction is presented as dynamic and complex self-organized systems.

With regard to the Open Systems group, ideas related to open systems, or those which present considerations that relate socio-environmental issues and concepts of open systems thermodynamics, were identified in some excerpts from the theses and dissertations. Seven of the twenty analyzed papers presented this idea in their discussions.

Table 3 Socio-environmental issues as Complex Systems

Groupings	Theses and dissertations	Extracts
Uncertainty	D1, T1, D3, D4, D5	The complexity in the real world would finally be taken into account, followed by interactions and feedback, by the character of uncertainty, recognizing order but also disorder, ending the era of absolute knowledge and absolute truth (D1, page 79)
Dynamics	T1, D3, T2, D12	It seems evident to us that the destruction of the variety of life (species or genetics) found in ecosystems, as well as the diminishing complexity of these ecosystems, lead us to a process of instability that causes damage by the simplifying action of man (Pena-Vega, 2005) (T2, page 85)
Open systems	T1, D3, T3, D6, D8, T4, D18	It is also pertinent to highlight that the systems can be open (where there is exchange of matter, energy, and information with the outside environment) or closed. In this perspective, García (1998) discusses the possibility of working with a system capable of preventing the dispersion of its elements, ensuring their autonomy and complexity, and which may be open to exchange, communication, among others (D8, page 26)

In the excerpt of dissertation D8 as an example of this grouping, presented in Table 3, the author uses the idea of open systems in her text to address socio-environmental issues. Particularly in this study, the object of study was the Physics curriculum in Brazilian basic education and its possible articulations with environmental themes. Part of the theses and dissertations indicate the relevance of considering the ideas of Morin and Lisboa (2015) when it comes to open systems. In the work of Morin and Lisboa (2015), there are considerations about the idea of open systems based on considerations of open thermodynamic systems. Other studies present the ideas of open systems in their discussion about environmental issues. In this way, ecosystems, soil, and human organization are being considered open systems. The Complexification category was built from a grouping called Environmental Complexity. This category refers to the ideas pointed out by Leff and Vieira (2001), especially those in which the author indicates that the understanding of socio-environmental issues must go through different ways of complexification.

Table 4 presents the systematized information regarding the Complexification category. With regard to Environmental Complexity, excerpts were identified in the theses and dissertations that show the links between Leff's idea of Environmental Complexity and socio-environmental issues. Four of the twenty analyzed papers present arguments that highlight this relationship. Regarding the excerpt from work D28, presented in Table 4, to exemplify this grouping, it can be highlighted that it points to the importance of Environmental Complexity for the construction of environmental knowledge. In this dissertation, there are several references to the works of Enrique Leff. Finally, it should be noted that, throughout the analysis process, many references were found to the works of Enrique Leff and Edgar Morin. In this context, these authors are the most important references in Brazilian theses and dissertations in the field of environmental education, especially when addressing concepts of complexities linked to socio-environmental issues.

3 Final Considerations

The analyses of the theses and dissertations indicate some relevant elements about the way the complexities are being presented in works in the field of environmental education that articulate with science education. In general, it seems relevant to indicate that considerations which address complexities related to socio-environmental issues seem to be a promising means for studies that articulate the field of environmental education and science education.

As mentioned in the introduction, this study is part of an effort by Brazilian researchers in the area of environmental education to map this field of knowledge. An important consideration for this study is the idea that complexity, in its broad and restricted sense, is of paramount importance for the understanding of environmental issues.

Analyzing how these meanings are presented in Brazilian theses and dissertations allows the academic community to ascertain an overview of the choices made by previous researchers, especially when considering that Brazil is one of the most influential countries in the southern hemisphere and has a national territory that holds one of the largest ecological reserves in the world.

Table 4 The complexification of socio-environmental issues

Groupings	Theses and dissertations	Extracts
Environmental Complexity	T1, T2, T5, D28	Environmental complexity demands, therefore, a reflection/action/reflection, praxis understood as a mobilizer of social changes, which requires environmental knowledge that brings together subjective and cultural aspects to the scientific disciplines, for glimpsing the critically and ethically responsible formation of the pupil towards planetary citizenship based on social equity and environmental quality (D28, pages 58 and 59)

The results obtained indicate that the works of Leff, Morin and Prigogine are the most referenced in Brazilian theses and dissertations which articulate environmental education and science education from discussions focused on the idea of complexity in its broad sense. In most of these studies, there is no interest in delving into the meaning of terms like complex systems. In this case, research is cited that deals with this subject in a very broad perspective; this is an aspect that may lead to severe criticism from researchers in scientific areas who deal with these ideas in a more restricted way.

The frequent citations to the works of Morin and Leff may show a preference of Brazilian researchers in the field of environmental education for the aspect of complexity linked to a science of light complexity, used by social scientists to change the patterns of understanding of social policies and the construction of complex thinking (Szekely & Mason, 2018). A compatible example is that a group of 12 theses and dissertations present excerpts related to the category of Complex Systems. This data indicates that a portion of the Brazilian researchers in the field of environmental education cites these ideas in a broader sense. However, as already indicated, many could invest in more dense exchanges on the conceptual terms with the field of hard sciences.

Another example is related with the category of Complexification. Four of the 20 analyzed studies consider the idea that socio-environmental issues are indeed related to Leff's idea of Environmental Complexity; and this, in turn, goes through different pathways of complexification. This result in particular draws attention, as it is the only reference directly related to the field of environmental education. The idea of complexification is a good example of complexity linked to a science of light complexity. Other theses and dissertations present considerations on socio-environmental issues based on articulations with the ideas of Prigogine's work. In fact, Prigogine is an author of the hard sciences, but the works referenced in most of the analyzed theses and dissertations are those that the author wrote with a view to scientific dissemination to the general public. In this context, these terms are presented in a broad sense.

The research herein was designed to analyze the meanings of the term "complexity" within Brazilian environmental education theses and dissertations when articulated with the area of Science Education. Complexities are a broad topic, with several meanings in the literature. This analysis allows us to have a glimpse at how this term presents itself in the Brazilian context when dealing with specific socio-environmental issues. The categories elaborated, as previously mentioned, are based on well-known references in the area, specifically in the Brazilian context, and the results found reinforce this.

Finally, the results indicate that the theses and dissertations analyzed present important contributions to the development of the field of research in environmental education in Brazil. It is considered relevant that these studies focus on discussions that articulate socio-environmental issues and complexity in a broad sense. However, even considering these contributions, this paper suggests expanding the dialogue and exchange with other areas of knowledge that have traditionally produced research focused on ideas of complexity.

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Declarations

Conflict of Interest The authors declare that they have no conflict of interest.

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