

ARTICLE

## INFLUENCES OF PARADIGMATIC CONCEPTIONS OF SCIENCE IN TEXTS ON ECOLOGY OF UNDERGRADUATES OF BIOLOGY SCIENCES<sup>1</sup>

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**ABSTRACT:** This article analyzed texts by undergraduates in Biological Sciences on the ecological theme, having as reference the paradigmatic conceptions of contemporary science: complexity, systemic and Cartesian. The research context was the Ecology Practice that is a curricular component of an undergraduate course in Biological Sciences at a public university in the Brazilian Northeast. The investigation employed a qualitative and quantitative approach with the objective of identifying the influence of paradigmatic conceptions of science in the construction of meanings of ecological themes by the undergraduate students participating in the research. The methodology combined the development of conceptual schemes and Statistical Implicit Analysis (SIA), which allowed viewing the implications of complexity and depth of the relationships established between conceptual variables present in the texts. The results indicated that different ecological themes suffer different paradigmatic influences. Systemic and complex conceptions were present in themes with conservationism and environmental impact, while

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consumerism was linked to the Cartesian paradigm. The research also corroborated the adequacy of mixed research approaches for the science teaching area.

**Keywords:** scientific paradigms, ecology teaching, environmental chronicle.

## **INFLUÊNCIAS DE CONCEPÇÕES PARADIGMÁTICAS DE CIÊNCIA EM TEXTOS DE LICENCIANDOS DE CIÊNCIAS BIOLÓGICAS SOBRE ECOLOGIA**

**RESUMO:** Este artigo analisou textos de licenciandos de Ciências Biológicas sobre a temática ecológica tendo por referência as concepções paradigmáticas da ciência contemporânea: complexa, sistêmica e cartesiana. O contexto da investigação foi o componente curricular Prática de Ecologia de um curso de licenciatura em Ciências Biológicas de uma universidade pública do Nordeste brasileiro. A investigação empregou uma abordagem qualiquantitativa com o objetivo de identificar a influência de concepções paradigmáticas da ciência na construção de significados de temáticas ecológicas pelos licenciandos participantes da pesquisa. A metodologia combinou a elaboração de esquemas conceituais e a Análise Estatística Implicativa (ASI), o que permitiu visualizar as implicações de complexidade e profundidade das relações estabelecidas entre variáveis conceituais presentes nos textos. Os resultados indicaram que diferentes temáticas ecológicas sofrem distintas influências paradigmáticas. As concepções sistêmicas e complexas estiveram presentes em temas como conservacionismo e impacto ambiental, enquanto o consumismo esteve vinculado ao paradigma cartesiano. A pesquisa corroborou, ainda, com a adequação de abordagens mistas de pesquisa para a área de ensino de ciências.

**Palavras-chaves:** paradigmas científicos, ensino de ecologia, crônica ambiental.

## **INFLUENCIAS DE CONCEPCIONES PARADIGMATICAS DE CIENCIA EN TEXTOS DE ESTUDIANTES DE LICENCIATURA EN CIENCIAS BIOLÓGICAS SOBRE ECOLOGÍA**

**RESUMEN:** Este artículo analizó textos de estudiantes de licenciatura en Ciencias Biológicas sobre el tema ecológico, teniendo como referencia las concepciones paradigmáticas de la ciencia contemporánea: compleja, sistémica y cartesiana. El contexto de investigación fue el componente curricular de Práctica Ecológica de la carrera de Ciencias Biológicas de una universidad pública del Nordeste de Brasil. La investigación empleó un enfoque cualitativo y cuantitativo con el objetivo de identificar la influencia de las concepciones paradigmáticas de la ciencia en la construcción de significados de los temas ecológicos por parte de los estudiantes de grado que participan en la investigación. La metodología combinó el desarrollo de esquemas conceptuales y el Análisis de Implicación Estadística (ASI), lo que permitió visualizar las implicaciones de complejidad y profundidad de las relaciones que se establecen entre las variables conceptuales presentes en los textos. Los resultados indicaron que diferentes temas ecológicos sufren diferentes influencias paradigmáticas. Las concepciones sistémicas y complejas estuvieron presentes en temas con conservacionismo e impacto ambiental, mientras que el consumismo se vinculó al paradigma cartesiano. La investigación también corroboró la idoneidad de los enfoques mixtos de

investigación para el área de enseñanza de las ciencias.

**Palabras clave:** paradigmas científicos, enseñanza de la ecología, crónica ambiental.

## INTRODUCTION

The teaching of ecology today has brought several challenges to teachers and students due to the numerous and complex issues associated with this discipline. Some of these challenges are related to the tradition of biology teaching and the exacerbated amount of terminologies and descriptions of processes and structures that often produces the image of a science of ready-made and finished truths (MOTOKANE, 2015). Others may be related to the curricular guidelines for basic education, in which the theme appears in a scant and low visibility, as is the case of the current Common National Curriculum Base (BNCC) (KRIZEK; MULLER, 2021).

Added to these challenges is the nature of the discipline itself, which involves the complexity of interactions between organisms and between them and a varied and changing world. Ecology itself as a discipline has grown and influenced the formation of new disciplines and new debates in many areas of knowledge. Its importance has long exceeded academic and school boundaries to foster new ways of thinking and acting in society. This understanding has affected our ways of teaching and learning ecology, since, from a conceptual point of view, in addition to understanding the network that forms living systems, their interconnections and interdependencies, it is desirable to distinguish the various ecology that coexist (natural or scientific ecology, human, social, political, deep etc.). (BOMFIM; KAWASAKI, 2015, JATOBÁ; CIDADE; VARGAS, 2009, MANZOCHI, 1994, LAGO; PÁDUA, 1985), as well as, its relations with contemporary scientific paradigms (complexity, systemic and Cartesian) (MORIN, 2002; MACÊDO, 2019, GONZÁLEZ, 2018, MOUL; SÁ; CARNEIRO-LEÃO, 2018).

If we talk about various ecologies it is because there are different ways of regarding this theme. In this work, we problematize the teaching of ecology from its polysemic dimension and adopt an epistemological and methodological path that evidences the influences of science paradigms on meanings of ecology triggered by undergraduates in Biological Sciences<sup>2</sup>. We have been dealing with this problem for about a decade as teachers of the discipline Practice of Ecology (three authors of this paper minister or have taught this discipline). It is a mandatory component inserted in the course matrix in the axis of "practice as a curricular component"<sup>3</sup> offered at the end of the course, usually after studying the disciplines of General Ecology and Conservation Biology<sup>4</sup>.

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<sup>2</sup> In Brazil, teacher training is carried out through undergraduate courses specific to the propaedeutic area (areas linked to general basic education formations such as Faculty of Arts, History, Sciences, Biology, Chemistry, Mathematics, among others) called in Portuguese as Licenciatura's degree. The courses in these areas are of two types: Licenciatura's degree, aimed at teacher training, and Bachelor's degree for generalist activities not linked to teaching. Thus, we can talk about a Licenciatura's degree course in Biological Sciences for the training of the biology teacher or a Bachelor of Biological Sciences for the professional biologist training.

<sup>3</sup> The practice as a curricular component is provided for in Resolution CNE/CP (National Commission of Education/Full Council) no. 2, of February 19, 2002 establishing the duration and workload of undergraduate courses, full graduation, training of basic education teachers at a superior level; and in Resolution CNE/CP n. 2, of June 9, 2015 establishing National Curriculum Guidelines for the Initial and Continuing Training of Professionals of the Teaching of Basic Education.

<sup>4</sup> The discipline Practice of Ecology was instituted in 2007 and until 2018 had as prerequisites the General Ecology and Conservation Biology. After that, for administrative reasons, it no longer had the prerequisites.

Being a discipline of practice as a curricular component, the Practice of Ecology had in its constitution critical references in the area of science education and boarded concepts and methodologies in tune with the human sciences. This condition conferred a space of expression of the mosaic of ideas that populate the scientific and social discourses on ecology, as well as their paradigmatic biases. In this sense, and from our practice and experience with this discipline, we ask in this work: what influences of paradigmatic conceptions of science can be observed in writing on ecological themes by undergraduates? Based on this question, we established as objective to analyze in which situations the paradigmatic conceptions (Cartesian, systemic and complexity) influence the construction of meanings of ecology by the undergraduates participating in the Practice of Ecology.

From this guiding question, we organize the work into three parts: the first is theoretical and thematizes elements of the advancement of ecology as science and politics, pointing out a possible reverberation of paradigmatic conceptions of science in its current meanings; the second presents the research methodology, explaining its context, the types of materials analyzed and the qualitative and quantitative path proposed by the application of the Implicative Statistical Analysis; and the third contains the interpretations of the results of the research in the light of the guiding question and the dialogue with the theoretical references.

We want to contribute to this work with practices and processes of research and training of biological science teachers, emphasizing the importance of ecology teaching from its many meanings that evoke paradigmatic conceptions.

## **ECOLOGY ON THE TREADMILL OF A PARADIGMATIC CHANGE**

Until the end of the 19th century, the relations between organisms and their environment were approached by naturalist scholars, without yet constituting an independent discipline of biology. There are reports that ecology would already be a curricular discipline in the United States in 1858; and that writer and naturalist Henry David Thoreau would have already mentioned it in his travel letters. Moreover, a definition of his would already be present in the 1859 writings of Charles Darwin and other scholars in the following years, even if there was, in fact, the nominated (ÁVILA-PIRES, 1999).

In 1866, biologist Ernest Haeckel then proposed the term "oecology" for the study of the economics of nature and the relationships of animals and plants with the environment and the term would have appeared for the first time in a footnote of volume I of his work. In the following years, Haeckel would have traced the relations of ecology with evolution and other disciplines and advanced in its definition, without, however, having highlighted or claimed its authorship (ÁVILA-PIRES, 1999).

In the 20th century, ecology developed and spread widely, building its own paths of investigation and interpretation, shifting the human being from an anthropocentric perspective to that of a link in the trophic chains and, thus, opening paths to an integrated vision that advanced the traditionally erected boundaries between the sciences of nature and human and social sciences. Being a science of relationships, ecology has given rise to a new way of thinking and relating concepts from different areas of knowledge, bringing important contributions to scientific and philosophical development.

For physicist and writer Fritjof Capra (2006), the problems of our time cannot be understood in isolation because they are systemic problems, that is, they are interconnected and interdependent. For

him, what is at stake is the "crisis of perception" established by a way of knowing that does not meet the complexity of a globally interconnected world. Change can only happen from a radical change in our shared perception, thought and values, which would result in saying, a paradigmatic change, as radical as the Copernicus revolution. Looking at the major changes that occurred in physics in the first decades of the 20th century, Capra acknowledges that a profound change in our worldviews, from a mechanistic vision, to a holistic and ecological view has been underway since then.

From the generalization of the concept of paradigmatic change that Thomas Kuhn attributed to science, Fritjof Capra sees the changes in physics and biology as part of a much broader cultural change, a paradigm shift that applies not only to the scientific field and to scientists, but to society itself. It is in this expanded sense that he defends the need for a new paradigm compatible with a systemic or ecological worldview, attributing here to ecology a much broader and deeper meaning than usual. The ecological perception of the world, for the author of *The Web of Life*, recognizes the fundamental interdependence of all phenomena and the fact that human beings participate and are dependent on the cyclical processes of nature. González (2018) recognizes the contribution of Capra and other important authors in the process of the paradigmatic sense of ecology constitution, such as Gregory Bateson and Edgar Morin. For him, the systemic or ecological paradigm continued to be problematized and developed by Morin resulting in the constitution of complex thinking.

In this sense, the designation of ecology as a paradigmatic reference refers, precisely, to this power to question the bases of the tradition of science and propose new lenses to understand the reality of the relations between environment and society. Not being part of the normal evolution of science, but an insurgency in its midst, ecology reached the revolutionary sense that Kuhn (2006) recognized in the history of science, a subversive sense that conferred condition for the emergence of a new vision on the relations between organisms and their environment until the resignification of the human being's place on the planet.

In paradigmatic terms, the expression of ecology has shaken well-established epistemological structures, such as the displacement of the Cartesian subject from its privileged position in relation to the other elements of the world and the profound questioning of the oppositions that are constitutive to it: subject and object, nature and culture, body and mind, reason and emotion, among others. Moreover, ecological investigations have contributed to the appearance of a new set of questions and problems situated beyond the so-called "two cultures" of Snow (1997), the natural sciences and of the humanities, since they are produced precisely in their intertwining and, therefore, dependent on renewed research practices for their interpretation and solution.

They were the environmental issues and problems that took place in the mid-20th century that further highlighted the importance of ecology knowledge and methodologies and gave them an even greater development. It was here, perhaps, that ecology left deeper paradigmatic marks influencing the creation of inter-disciplines and areas of knowledge or structurally modifying existing ones. However, the influence of ecology was not contained in the academic context or restricted to a scientific ecology, since it expanded to the broader social context, composing a field of struggles and denunciations against the opulence and predation sustained by modern industrial societies (JATOBÁ; CIDADE; VARGAS, 2009).

In fact, the deepening of modernization processes and the proliferation of risks associated with scientific and technological advances have led to the definition of an urgent and planetary environmental problem, epistemologically situated in place of frontier, between established knowledge

and others not so considerable: science, politics, nature, culture, religion. Some contemporary authors who have been dedicated to the study of issues related to the environment and environmental movements, especially in the field of interdisciplinary research, often see in them an opportunity – and a possibility – to make a profound questioning of society-nature relations, which refers to a strong criticism of the epistemological, social, cultural and political canons rooted in the systems of thought and in the forms of organization of the current societies. Alongside the pluralist status of the very notion of nature and the socially constructed character of the environmental issue, it is common to emphasize and concern with themes of a pragmatic order, of explicitness and critical evaluation of the conditions of viability of approaches that actually operationalize the idea of "socio-environmental sustainability" (VIEIRA; WEBER, 1997).

Despite the visibility that planetary environmental problems have assumed in the present and their constancy in the social life of modern societies, political formations and instances of research, planning and execution have proved incapable of grasping the problem in the set of its implications. And not only because the proposed solutions are based on a technocratic and reductionist point of view, to which we have been immersed for many decades, but because, more recently, they have also become targets of denialist and antiscientific attacks (DANOWSKI, 2012, SANTINI; BARROS, 2022).

Leff (2011) considers that the socio-environmental problem calls into question the established paradigms of current knowledge and demands new perspectives and methodologies that can guide a process of reconstruction of knowledge in the sense of an integrated analysis of reality. This is because such issues conjoin natural and social processes of different orders of materiality, and cannot be understood in their complexity without the contest of fields other than knowledge. Although difficult to rebut, this premise has demonstrated many difficulties in the practical field and has led to difficult changes in all societies, precisely because they are dependent on another rationality or, in terms of this work, another paradigm.

### **Ecology and paradigms of science: making conceptual correspondences**

According to Macêdo (2019), scientific paradigms can currently be classified into three types, Cartesian, systemic and complexity. According to the author, the Cartesian paradigm has been dominant since its appearance around the 17th century and presents as characteristics the verticalization, reductionism and specialization of knowledge, besides promoting dichotomous distinctions between science and ethics, subject and object, qualitative and quantitative. The systemic paradigm, on the other hand, was established as an opposition to the current paradigm and promotes the articulation between the parties and the whole, shifting thinking between the systemic levels in a network dynamic. In turn, the complexity paradigm is characterized by the cognitive articulation that emerges from the union between the in-depth knowledge of the parties, constituted by Cartesianism, and the interrelations between the parties and these with the whole, which constitutes the systemic paradigm, in a way that addresses inter-systematic ideas.

For González (2018), the systemic paradigm, which he calls as ecological is a complex aspect of thought. In agreement with this statement, we can quote Mariotti (2000) who stated that the complexity paradigm is represented by the embrace between Cartesian and systemic paradigms. complexity does not deny the previous paradigms, especially the Cartesian, but is constituted by the full interaction between the two paradigmatic bases. For González (2018), complexity is not yet a normalized

paradigm, it is in development and much is missing for it to be normalized as the dynamics of scientific development that Thomas Kuhn advocates.

Since ecology is the focus of the transformations of science, we propose in this work a correlation between the paradigmatic conceptions of science and the different perspectives of ecology presented by Jatobá, Cidade and Vargas (2009), they are: radical ecology, moderate environmentalism and political ecology.

Radical ecology is the perspective that is born together with scientific ecology and is expressed mainly in preservationism, conservationism, deep ecology, ecological economy and other movements considered traditional. In this perspective, a rigid biocentric perspective prevails, whose exemplary territorial expression is the creation of areas of integral protection, that is, with or without minimal human presence. The policies and strategies associated with radical ecology are varied and, according to the authors, "a common trait between them is the submission of economic and social aspects to the ecological approach" (JATOBÁ; CIDADE; VARGAS, 2009, p.9). Although this perspective has been indispensable for the development of an ecological awareness, its brand is the impossibility of reconciling economic, ecological and social objectives.

Towards a conciliatory vision, the so-called moderate environmentalism seeks to combine the principles of radical ecology with the objectives of economic growth, sociocultural development and environmental conservation. From this perspective, proposals for eco-development and sustainable development took place. It is noteworthy that the notion of eco-development predate that of sustainable development was first used in 1973 by Maurice Strong. For Sachs (1993 apud JATOBÁ; CIDADE; VARGAS, 2009), eco-development is defined as an intermediate path between "uncompromising ecologism" and "narrow-vision economism", he advocates the revision of the economic model, overcoming poverty and the destruction of the environment and greater economic justice for developing countries. The notion is multidimensional: social sustainability, economic sustainability, ecological sustainability, spatial sustainability and cultural sustainability (JACOBI, 1999).

The concept of sustainable development was disseminated in 1987 by the Brundtland Report, as is also known by the Report of the World Commission on Environment and Development. According to Jatobá, Cidade and Vargas (2009), this concept contemplates a more moderate proposal than eco-development and has therefore been repeatedly used in world conferences promoted by the United Nations and in the policies of most countries. Its greater acceptance and diffusion do not eliminate however, the tensions present around a term so polysemic that it promises to combine two distinct types of rationality, economic and ecological.

The third perspective, political ecology, criticizes the previous two and seeks to advance the debate on environmental problems, emphasizing socioeconomic, political and ideological contexts. Political ecology seeks foundations in critical theories of society and aligns itself with the contestatory social movements, such as environmentalists, racial and feminist, that arise in developed countries, but also and especially in the context of social and environmental injustice that characterizes the history of developing countries. According to Jatobá, Cidade and Vargas (2009, p. 22) political ecology "postulates that environmental problems cannot be understood isolated from the political and economic context in which they were created. It is necessary to relate socioeconomic and political processes and social actors at the global, regional and local levels." In this sense, at the center of the debates of political ecology are socio-environmental conflicts as a reflection of a deeply unequal and socially unjust society socially and environmentally. "Only through a political approach to social and environmental issues can a new balance

of forces be sought between social actors, generating greater justice in the distribution of burdens and benefits arising from environmental changes" (JATOBÁ; CIDADE; VARGAS, 2009, p. 30).

From these three ecological perspectives, we propose the following correlation: radical ecology tends to reductionist premises, which is typical of the Cartesian paradigm; the perspective of moderate environmentalism advances to relations with human practices of a socioeconomic nature, establishing the consideration of ecological relations with the humanities and approaching a systemic paradigmatic perspective; and political ecology, by fully including human beings and their cultures in the ecological sphere, begins to consider an understanding of the ecology of the human, social, political and natural sciences, establishing itself as a perspective based on complexity.

The correlation proposed here does not intend to close the ecological perspectives presented within a rigid framework of paradigmatic conceptions, as if they were rigidly closed categories. Neither paradigmatic conceptions nor ecological perspectives can be considered, as they harbor within them a fluid gradient of currents. What we propose is the use of these conceptual concepts to support a theoretical and methodological approach, whose path we present in the sequence.

## **METHODOLOGY**

In line with what we developed throughout the article, the methodology aimed to use qualitative and quantitative research approaches in a complementary way. With this mixed approach, which we call qualiquantitative, we seek to explore in a more complex or ecological way the phenomenon researched. Following the words of Minayo and Sanches (1993):

The relationship between quantitative and qualitative, between objectivity and subjectivity is not reduced to a continuum, it cannot be thought of as contradictory opposition. On the contrary, it is to be desired that social relations can be analyzed in their most "ecological" and "concrete" aspects and deepened in their most essential meanings. Thus, the quantitative study can generate questions to be deepened qualitatively, and vice versa (MINAYO; SANCHES, 1993, p. 247).

In this topic we present the contextualization of the investigation, the methodological design that includes the procedures and research instruments and the forms of analysis employed.

### **Contextualisation**

The research was carried out from teaching activities conducted in a class of the discipline Practice of Ecology a mandatory curricular component offered in the undergraduate course in Biological Sciences of a public university located in the Northeast of Brazil. This discipline composes the eighth period of the curricular matrix of the course as "practice as a curricular component", and was created in compliance with curricular reforms deliberated by the National Curriculum Guidelines of 2002 for teacher education (BRASIL, 2002).

The discipline had as prerequisites two other disciplines, General Ecology and Conservation Biology. In addition to the considerations of scientific and conservation ecology addressed by these disciplines, the Practice of Ecology aims to expand the formative scope by presenting historical, anthropological, sociological and political tendencies involved in environmental studies.

The teaching plan of this discipline was constructed with a view to basing a critical formation



about ecology, its multiple meanings and relationships with various fields of knowledge, besides relating ecological concepts with the context of life and with discussions about scientific paradigms and ecological perspectives guided by sustainability. In this sense, various activities were proposed throughout the discipline, such as photographic narratives of ecological situations in the surroundings, conceptual schemes in groups and shared reflection in the classroom, as well as the production of texts of the chronicle genre as part of a collective project to produce a carton book<sup>5</sup>.

The activity of writing authors chronicles, it is worth saying, non-academic textual genre, constitutes a singular practice in the general context of the course. Generally, when we present the proposal to a new class, there are curiosities of some and sometimes strangeness of others. In fact, the proposal emphasizes a personal writing, therefore, freer, without the ties of conventional academic writing. It was agreed with the class that the first version of the text would be presented for dialogue with the teacher of the discipline, then return to the author for review or rewriting, until the final delivery that would make up the collective work.

This teaching proposal encountered initial resistance on the part of undergraduates who had expectations of attending a discipline based on the conditions of the bachelor's degree where they would have ecology practices conducted in the field or in the laboratory, for instance. This situation reflects the conditioning to the Cartesian paradigm that permeates the educational structure in which we are immersed. This even reverberates in paradigmatic conditions of practical order in the exercise of teaching (MOUL; SÁ; CARNEIRO-LEÃO, 2018). For Behrens and Rodrigues (2015), traditional pedagogical practice is related to the influences of the Cartesian scientific paradigm, and emerging or innovative practices tend to rely on systemic and complexity scientific paradigms, establishing new practices.

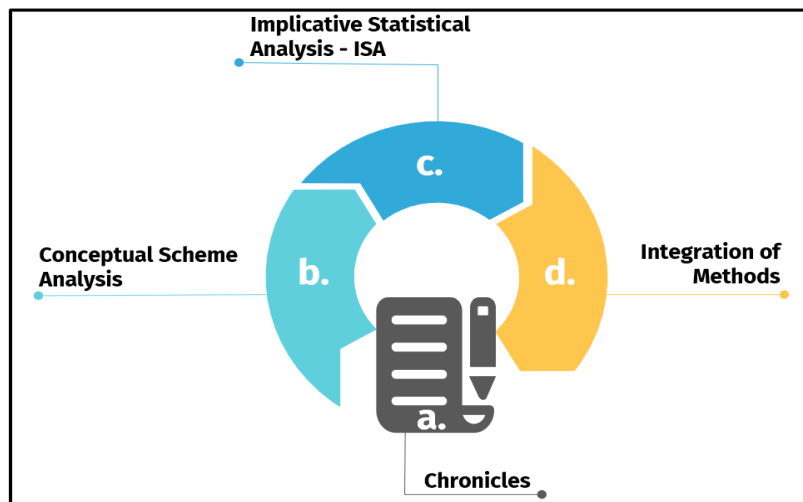
## **Methodological Design**

The methodology used four main procedures: a) texts of chronicles produced by undergraduates; b) text analysis and elaboration of conceptual schemes; c) Implicative Statistical Analysis; and d) empirical-theoretical articulation of the texts of the undergraduates, ecological perspectives and paradigmatic conceptions. Figure 1 illustrates the main moments of the research.

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<sup>5</sup> The production of carton books in the discipline Practice of Ecology has been developed since 2013. The pedagogical proposal is inspired by the "cartonero movement" (SIQUEIRA, 2019) and its principles are the use of resources, authorial writing, the relationship between science and art and socio-environmental citizenship. Participants prepare critical texts and collectively edit a physical book with handmade covers made of cardboard. At the university, in addition to a teaching project, this is also an extension and research project.

Figure 1: Methodological design



Source: own authorship.

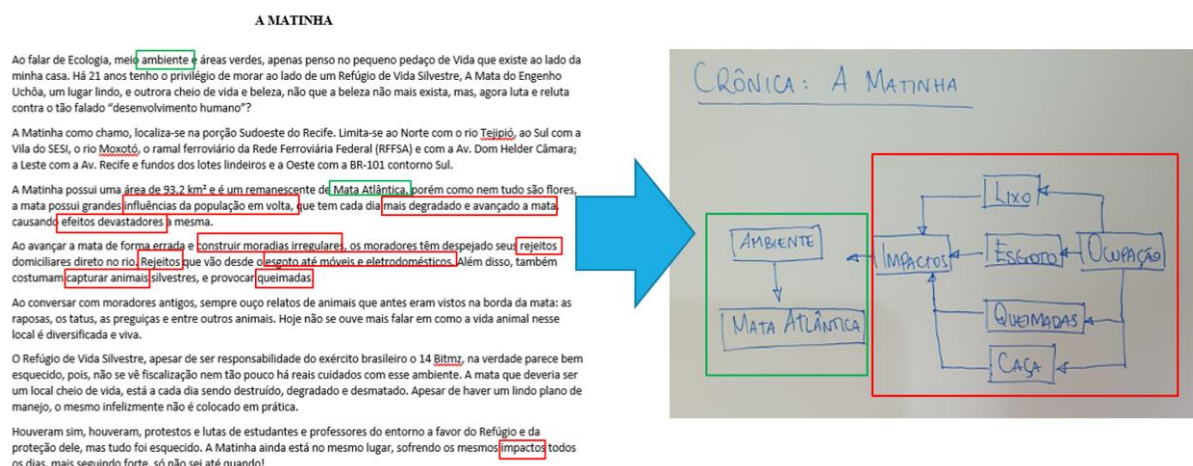
### a) Production of chronicles

As mentioned earlier, this analysis considered the final version of the 34 (thirty-four) chronicles with ecological themes produced by biological science graduates, as presented in the contextualization. It is worth mentioning that, although the textual genre in question is freer, some guidelines were given for its writing: short text of up to 3 pages; address an ecological-environmental theme related to the life of the author of his/her choice; bringing issues that may be of interest to a broad audience; present plausible knowledge; and a personal opinion.

### b) Text analysis and elaboration of conceptual schemes

Each chronicle was read and interpreted individually, to highlight concepts and their related terms associated to ecology. From this textual analysis, conceptual schemas were elaborated (by the first author of this article), as exemplified in Figure 2.

Figure 2: Example of analysis of an original chronicle through conceptual schemes in Portuguese



Source: Elaboration of the first author.

In this work we used the term "conceptual schemes" to designate a particular way of organizing concepts and other knowledge, more flexible than conceptual maps. For Ferrão and Santarosa (2020), conceptual maps are tools for representing a text that allow organizing propositions and concepts at hierarchical levels of relationship. This hierarchical relational representation of concepts present in a text allows us to represent textual discourse through the articulation of discursive objects, which in the field of science teaching, we can understand as scientific concepts.

In the case of conceptual schemes, we follow the meaning employed by Müller (2014) who considers them more flexible than conceptual maps, precisely because it allows the composition between concepts, but also between these and events and phenomena. Regarding this work, we adapted the term to also include other terms that are organized around a central ecological theme, which can be themes, processes and even artifacts. For example, the terms linked to the concept of biome can be: garbage, plastic, oil, deforestation, industry, beach, sea, ocean, corals, etc.

### c) Implicative Statistical Analysis (ISA)

Once the textual analysis stage was completed, the concepts and terms found in the first stage were submitted to Implicative Statistical Analysis (RÉGNIER; ANDRADE, 2020). They were categorized, tabulated binarily (0 and 1 – does not contain and contains, respectively) and related to the textual production of each student in a Microsoft Excel® spreadsheet, suitable for analytical reading performed by the software Hierarchical Classification Implicative and Cohesive (CHIC) version 7.0 (2014).

The Implicative Statistical Analysis (ASI) is a theoretical field based on the concept of statistical implication or, more precisely, on the concept of almost implication to distinguish it from the logical implication of the fields of mathematical logic (A.S.I. 11, 2021). According to Gras and Régnier (2015) the reasoning that supports the interpretation of the results of the implicative analysis is essentially statistical and probabilistic in nature. The strength of an association between two variables is measured by probability  $P(N_{ma} < n_{ma} \mid \text{independence})$  – that, in the case of independence, the number of occurrences ( $N_{ma}$ ) is weaker than the number actually observed ( $n_{ma}$ ) (ORIS; RITSCHARD; PERROUX, 2013).

In this work, the ISA was calculated according to the mathematical condition selected in the CHIC 7.0 software (2014) considering the significant "nodes", classical theory and binomial law enforcement. The analytical expression of the data chosen was that of the implicative graph for implication relationships with a **minimum implication index of 0.75**.

The variables (concepts and related terms) are presented in parentheses and are integrated into the descriptive and analytical text about the relationships between them. Thus, according to the number of variables related in the text, the constructed meanings were classified into **Cartesian conception, when they articulated up to five variables; and in systemic-complex conception when more than five conceptual variables were articulated**. The delimitation of the number of relationships between variables and their characterization according to scientific paradigms is justified on the grounds that: (1) the articulation of up to five variables represents a tendency towards the reductionism that structures the Cartesian paradigm, in other words, the texts tend to present a central concept or theme with few relationships with other concepts and themes; (2) as the authors use more than five concepts relating them to each other, we see that the chronicles present richer narrative

structures that are not tied to the focal concept, but allow for other considerations that give new meaning to the central concept of the theme addressed. We would like to point out that the considerations about the number of relationships between the concepts present in the chronicles meet the limitations of this textual style, a free textual production characterized as a short text, with an average of 600 characters.

The result can be interpreted by reading the implicative graph where a certain conceptual variable implies another. For example, addressing marine ecology implies that the student contemplates topics related to pollution, then plastics, which imply microplastics, which cause the death of marine organisms, etc. This line of reasoning seems logical, but it is the result of the student's experience and knowledge that form meanings built on ecology.

We emphasize that the analysis based on classification in concepts and related terms can restrict the complexity of relationships that is infinite, but finite in the individual conception. However, this organization of the implicative graphs has a didactic character to better visualize the interactions in order to understand how these systemic "webs" can be formed.

In this study, data analysis followed distinct and complementary stages, as shown in figure 1. In view of the complex structure of the analytical organization, it is pertinent to explain that after the individual analysis of the chronicles, in which we obtained the identification of the concepts and their relationships, the ASI framework is applied as an integrative and holistic method of all the data constructed with the conceptual schemes and respective identifications of the paradigmatic nature of each chronicle. In this way, the implicative graph (a graphical and analytical tool constructed through implicative statistical analysis) used in the results presents the conceptual relationships and characteristics of each chronicle in a complete and integrated perspective. Although the figures look like different implicative graphs, they are cut-outs of a single implicative graph that relates all the chronicles in a complex and holistic analysis. In all the figures, the exact location of the relationships that are highlighted in the analysis of the results will appear below.

This favors the interpretation of paradigmatic influences for the group considered in this research and contributes to data analysis from a complex perspective: firstly, because, according to Morin (2000), complexity is the union between unity and multiplicity; and secondly, according to Santos de Aquino (2022), the large number of dependent and independent variables that exert their influences on a given research object in the human sciences makes it impossible to control and standardize the coefficients of variation, a fact that favors ASI as a suitable method for studies in the educational sciences and brings it closer to complexity.

#### **d) Empirical-theoretical articulation**

The results obtained by the production of conceptual schemes associated with ISA allowed us to advance in an analysis and reflection articulated to the theoretical framework of scientific paradigms (MORIN, 2002; BEHRENS; RODRIGUES, 2015, MACÊDO, 2019), of ecological perspectives (JATOBÁ, CIDADE E VARGAS, 2009). By cross checking the empirical material resulting from pedagogical work in the classroom and theoretical elaborations, we were able to understand more widely the correlations and influences that are produced in the teaching and learning of ecological themes.

## Ethics in research

The materials used in the analysis came from the normal development of the teaching practice of the authors of this study and fall within the scope of Article 1 of CNS<sup>6</sup> Resolution 510 of 2016: "single paragraph: They will not be recorded or evaluated by the CEP/CONEP<sup>7</sup> system: VII - research that aims at the theoretical deepening of situations that emerge spontaneously and contingently in professional practice, as long as they do not reveal data that can identify the subject."

In compliance with the ethical standards in research with human beings, in this work the identity of the students or any information that can identify them, such as university, course period, and the school year, semester and shift were not mentioned. The copyright identities of the texts of chronicles were neither computed nor revealed, and only the title and body of the texts of chronicles were used in the study.

## PARADIGMATIC INFLUENCES ON THE CONSTRUCTION OF MEANINGS IN ECOLOGY

Proposing activities that seek to activate a systemic-complex thought is not trivial, since the consequent break of the linear logic characteristic of the Cartesian paradigm brings challenges to teachers and discomfort to students who may present a reactive behavior to unconventional methodologies.

The expectation of undergraduates with the practical curricular component of Ecology is usually to develop an extension of the components General Ecology and Conservation Biology, almost in the baccalaureate model, with studies on the interactions between non-human species, their populations and communities and the environment, biomes and ecosystems, preservation and conservation etc. Thus, it is common to expect to approach the teaching of this area based on the ecological type that passes between what is called perspectives of radical and moderate ecology, in which the human is still understood outside ecology or only a factor of its disturbance (JATOBÁ; CIDADE; VARGAS, 2009). When anthropic action in the environment is considered, understanding is usually based on economic moderation as a reductionist interpretation of sustainability. These observations we make from the practical experience of the classroom, which leads us to invest in various pedagogical moments to agree on different teaching and learning modes and activities.

Regardless of the usual initial difficulties, the development of the Ecology Practice usually obtains engagement of the undergraduates, especially through the writing of the chronicles. In this case, 34 chronicles were produced. As previously described, we used as a method of analysis the elaboration

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<sup>6</sup> CNS (National Health Council) is the Brazilian organization responsible for the legislation of ethics in research and for the application of laws and norms through ethical appreciation in scientific research projects with human beings.

<sup>7</sup> CEP (Research Ethics Committee) is a local organization, established by a commission in each of the higher educational institutions as federal, state or private-public universities that act with research, as well as public or private research municipalities and research foundations that act in Brazil. CONEP (National Research Ethics Commission) has national coverage, both committees are instituted under CNS standards. The CEP/CONEP system is responsible for law enforcement by conducting the assessment of ethics in scientific research, where CEP composes the initial assessment at the local level, i.e., specific research institutions (universities, federal institutes, research institutes) and CONEP carries out the secondary assessment at the national level. The CEP/CONEP system carries out the activities of assessing ethics in research projects through the Brazil Platform, a digital means through which projects, evidential and mandatory documents are available, in addition to the ethical assessment opinions issued and the communication between committee members and researchers who postulate research projects for ethical assessment.

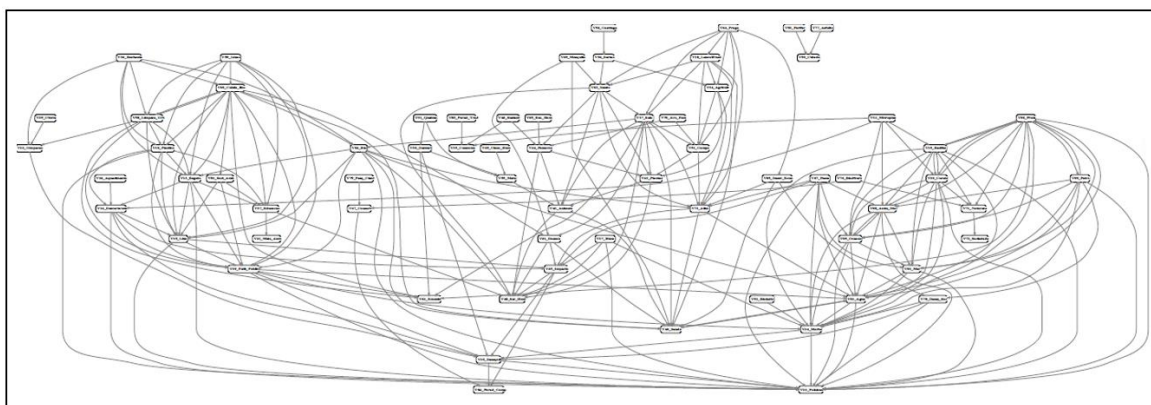
of conceptual schemes to identify the concepts and related terms and point out the paradigmatic influences, allowing us to classify them according to cartesian scientific paradigms and the systemic-complexity paradigmatic perspective.

When confronting the set of conceptual schemes, we identified only 3 (three) of them associated with the Cartesian conception because they present relationships with up to 5 conceptual variables; and 31 (thirty-one) presented relationships with more than 5 conceptual variables, thus being consistent with the systemic-complex paradigmatic conception. The observation of reductionist relationships is easy to be perceived because they merely describe a chain between variables that reflect the cause-effect relationship. In addition, few variables or concepts are considered in the conceptual articulation, usually constructed from a line of reasoning that links primary concepts in order of cause and effect and reductionist sequence. In these cases, variables or concepts that relate to this primary line are disregarded limiting the construction of meanings. We noticed that chronicles with more than five conceptual variables considered one or more secondary concepts, promoting a construction of meanings in a systemic-complex perspective. In total, we noticed 85 (eighty-five) conceptual variables, and only 69 (81% of the total) of them presented relationships of statistical implication.

Works that integrate the ISA to understand paradigmatic, philosophical and cultural influences in the construction of meanings and concepts have already been carried out. These studies indicated the potential of ISA as a statistical method applied to mixed methodological perspectives. Examples of studies of this nature are the work of Fazio and Spagnolo (2008) who investigated the philosopher-methodological influence (constructivism, Aristotelian-Galileo, Platonism, etc.) of undergraduate students of the Secondary Education Teachers Course at the University of Palermo in Italy who wished to act as professors of mathematics and physics; another example was the mathematics learning strategies used by Chinese and Italian students researched by Di Paola and Spagnolo (2009), where the use of ISA allowed analyzing the way of thinking and the behavior of students; and more recently the influence of the paradigmatic perspectives of high school students in the Brazilian semi-arid region on the construction of concepts about the Caatinga biome (SANTOS; SANTOS DE AQUINO; RAMOS, 2021).

The general implicative graph (75% of the level of implication) is shown in Figure 3. We emphasize that its illegibility is due to its size, resulting from the complexity of the conceptual relationships established, which justifies its insertion in this article. However, to give readability to the results found, throughout the exposure we will use clippings, always identified inside the general implicative graph.

**Figure 3: Complete implicative graph with 69 variables with statistical implication relationships**



Source: Graph obtained through CHIC v. 7.0 software (2014). [Due to its illegibility, the figure is merely illustrative of the complexity of conceptual relationships].

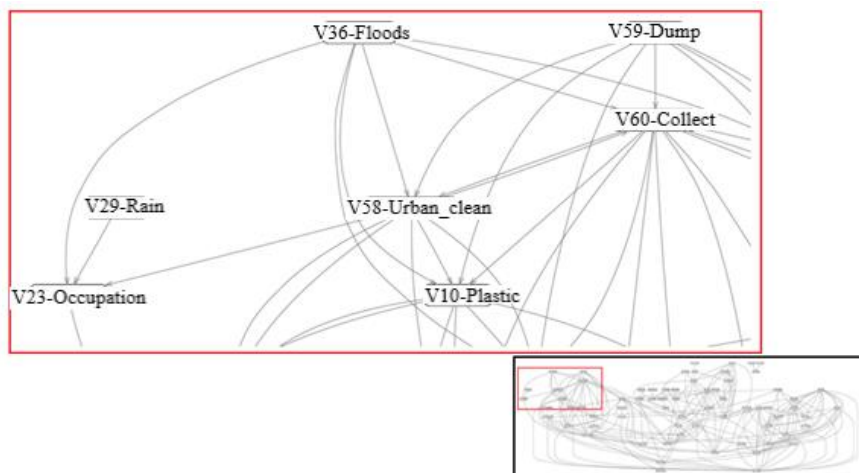
In the implicative graph we focus the observation on the network formed by the connection of 69 conceptual variables. Each line starts in one variable and ends in another, always indicated by the direction of a terminal arrow. This representation means that a given variable **A** implies another (other) variable(s) **B** (or **C**, **D**, etc.). This implicative graph will be analyzed using cut-outs in the following figures.

On the topics addressed, 34% corresponded to marine pollution, mainly bringing the case of the oil disaster on the beaches of Northeastern Brazil<sup>8</sup> and plastic pollution. Other themes were identified, such as urban pollution, disordered urban growth, deforestation, floods, adaptation of wild animals to urban life, environmental impact caused by road traffic due to trampling of native species among others.

The graph can also be understood as a complex network formed by 69 conceptual variables and reveals a systemic and/or complexity representation on the theme Ecology that was treated in the set of environmental chronicles. Each text dealt with independent themes related to the theme chosen by the male and female students. It is important to highlight that even when the chronicle dealt with the same ecological subject, as was the case of marine ecology, the construction and concepts used were not exactly the same. This materializes the existing complexity on the content of Ecology, having extensive possibilities of relationships.

For a better understanding of this graph, we will read and interpret it in parts, starting with Figure 4, which deals with the garbage problem and its consequences which are related to other variables related to issues such as social and environmental public policy and education.

**Figure 4: Partial view of the implicative graph of conceptual variables related to rainfall and floods**



Source: Graph obtained through CHIC v. 7.0 software (2014) and adapted using Microsoft Paint3D. The red frame corresponds to the region of the implied graph under analysis.

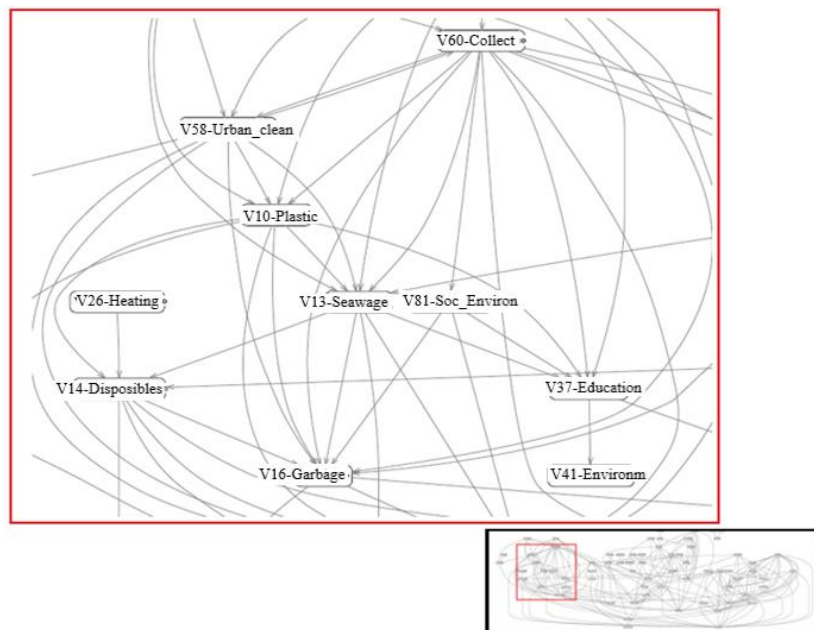
It is possible to notice that thinking about the effects of rain (V29-Rain) or floods (V36-Floods) implied thinking about the occupation of space (V23-Occupation), relating the effects of rains and floods (as a rainfall effect) with the disordered occupation of large urban centers. The understanding of the conditions of occupation of space by human beings returns to the scene in the themes of dumps, garbage collection and urban cleaning. The implication of these variables shows some articulated reflection of natural phenomena (rain and its effects, such as floods) to anthropic factors such as pollution

<sup>8</sup> The oil disaster on the coast of Pernambuco and other states in the Northeast generated social mobilization and voluntary actions to clean the beaches. Some of the consequences, can be seen in Araújo, Ramalho and Melo (2020).

(garbage treatment and disordered occupation).

Figure 5 shows that the garbage problem and its consequences are related to other variables related to issues such as social and environmental public policy and education.

**Figure 5: Partial view of the implicative graph of conceptual relations related to garbage, public policies and education**



Source: Graph obtained through CHIC v. 7.0 software (2014) and adapted using Microsoft Paint3D. The red frame corresponds to the region of the implied graph under analysis.

Garbage collection (V60-Collect) implies articulating the problem of plastic garbage (V10-Plastic), river pollution, and variables linked to public policies (V39-Public Policies) in the socio-environmental (V81-Soc\_Environ), health (not visible in figure 5) and education (V37-Education) areas.

In parallel, thinking about the problem of plastic implies relating this theme to disposables, to sewers (the Arruda canal in Recife/PE – a stream that was transformed into sewage – having been cited in two chronicles) and about education and public policies as ways to solve the problem.

On global warming, when addressed, presented implication with the consumption of disposable products, which, in turn, implied with the theme of pollution in the environment, consequently in environmental imbalance (directly implicated with damage to the ecosystem). And microplastic implies the understanding of disposable garbage (relationships not fully visible in Figure 4 and impossible to be represented in the space of this work, since they cross the graph in its entirety).

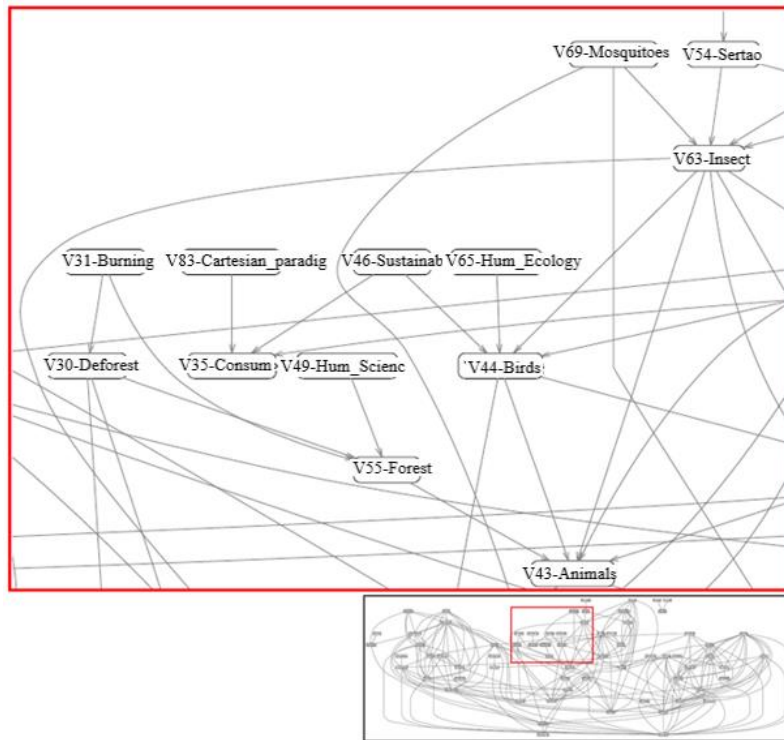
In Figure 6, we visualize an area of implicational relations that portrays how the human sciences (V49-Hum\_Sciences) are understood by undergraduates when thinking about ecology. The variable (V49-Hum\_Sciences) was identified in chronicles that directly explained the human sciences relating this field to the conservation of forests (V55-Forest). Thinking about sustainability (V46-Sustainab) implied reflection on the presence of birds in their diversity (V44-Birds) and in the relationship with the consumerist habit of modern society (V35-Consum). Like the human sciences, human ecology (V65-Hum\_Ecology) was related to the presence and diversity of birds (V44-Birds).

Such relationships show how superficial the understanding of the importance of the area of humanities in biological sciences courses for the studies of ecological themes is, although human sciences are often cited. This seems to stem from the fact that, for many, the Practical component of Ecology is



associated with traditional scientific ecology, and in this sense may dispense with the complexity of the human-environment-society relationship<sup>9</sup>.

**Figure 6: Partial view of the implicative graph of conceptual variables related to human sciences**



Source: Graph obtained through CHIC v. 7.0 software (2014) and adapted using Microsoft Paint3D. The red frame corresponds to the region of the implied graph under analysis.

At one point, we realized that discussions involving the topic of social policies sounded strange to a part of the graduates. For example, garbage as an impacting factor in the environment was easily identified and discussed in several textual productions, but the relationship of causes linked to human consumption was not effective, because it was summarized to the direct causative relationships to the environment characteristic of common sense. This reductionism is one of the characteristics of the Cartesian paradigm, and is easily identified in the students' productions, evidencing that the themes garbage and consumerism (this relationship will be presented below), despite being recognized as environmental problems, are still perceived superficially when trying to reflect on the origins of these issues. In these relationships there is a subtraction of economic and social aspects. As the conceptions about the ecological problem of garbage were limited to the causality of Cartesian logic, it was not reflected on the role of human sciences related to ecology, placing these relationships in the perspective of a radical ecology (JATOBÁ; CIDADE; VARGAS, 2009).

In an attempt to discuss the ecological relationships of garbage and consumerism, the students ended up not considering aspects that contribute to the environmental impact caused by garbage and that are situated in the human and social sciences. According to Silva et al. (2015) the ecological impacts and imbalances on biogeochemical cycles are due to political and economic decisions and that the solution of such problems requires changes in power and production structures and not superficial

<sup>9</sup> On the importance and strategic role of the humanities for national development under various approaches, including environmental, it is suggested to consult the Diagnostic Report of Humanities, Applied Social Sciences, Linguistics, Languages and Arts (CHSSALLA) in Brazil (Center for Management and Strategic Studies, 2019).

and palliative measures on their effects. Bolzani and Colombo (2019) link the anthropocentric culture as legitimizing archetypes of domination, submission and exploration of nature, as much as it broke with the ancestral metaphysics that was present in relations with the natural environment. Explaining about the production of garbage and its impacts without considering the human and social relations that direct this ecological relationship between human beings and nature reduces ecology to a perspective unrelated to human practices, excluding the human being from ecology. The non-consideration of human complexity in environmental impacts reinforces the Cartesian and anthropocentric view, because as pointed out by Bolzani and Colombo (2019) reinforce the reduction of ecology to the anthropocentric perspective that nature, destined to serve humans, should be understood separately.

When the issues are situated at the level of radical ecology (JATOBÁ; CIDADE; VARGAS, 2009), where a pure nature subtracted from human beings is considered, the understandings about ecological relations are diversified by considering the various relationships between non-human animal species and plants and the natural environment. In other words, the reflection on ecological problems was reduced to nature, being considered direct and indirect relationships that facilitate the construction of systemic meanings, but without including political and social relations belonging to the anthropic dimension. An example of this can be extracted from a branch of the graph where insects compose an implicative nucleus and we can perceive the influence of the complexity paradigm from a radical ecological perspective: the writing around insects (V63-Insect) has led to reflections on two entomological groups: mosquitoes (V69-Mosquitoes) and agricultural pests (V64-Plague). The two classifications of insects were related to the environment of the semi-arid northeast (V54-Sertao), where they were related to ecological imbalances, resulting in the spread of diseases and contamination of groundwater (V18-Groundwater) by the use of pesticides.

To understand the presence of the implicative relationship of groundwater with insects, it is worth reporting the implication between the variables plague (V64-Plague) and groundwater table (V18-Groundwater). This relationship was established between control of agricultural pests with pesticides causing contamination of the groundwater, which, in turn, implies the relationship with the variable insect (V63-Insect).

Thus, dealing with insects (V63-Insect) implied in the relationship with other concepts and related terms, such as humans (V48-Human), birds (V44-Birds) and animals (V43-Animals) due to the composition of the trophic chain: hematophagous insects and disease vectors to animals and humans have as a way of controlling the predation of birds. They also imply another aspect related to agriculture, since insects are related to the understanding of soil pollution (V17-Soil) and food (V73-Food), because they require, in conventional agriculture, chemical control contaminant in the environment.

Understanding the insect-pest required, also, implication relationships with chemical control of agricultural pests (V34-Agriculture) and consequent contamination of soils (V17-Soil), groundwater (V18-Groundwater), rural environment (V51-Field), human health problems (V40-Health) and example of economic development (V85-Economic\_develop), since for large-scale food production procedures of agricultural pest control are required.

In this description of insects, we have an excellent view about the complex thinking in the construction of implicative relationships between categories linked to ecology. A similar situation occurs when the theme was marine ecology associated with the discussion of the case of petroleum pollution (V09-Petroleum) on the beaches of Northeastern Brazil in March 2020.

Discussing about oil involved the approach on pollution (V22-Pollution) related to marine

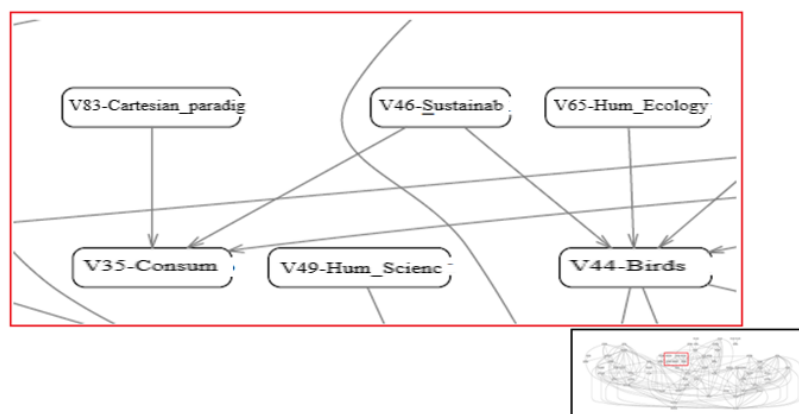
ecology as ocean, sea, beach and marine animals (V05-Ocean, V03-Sea, V06-Beach, V08-Marine Animals) and social imbalance (V78-Social\_imbalance), for affecting people's lives, specifically from riverside communities, such as fishermen' communities.

Consequently, we highlight that thinking about the ocean was an exercise resulting from discussions about oil on beaches, impacts on coral reefs, fishing conditions and the diversity of marine animals, as well as contamination of ocean waters by microplastics (V12-Microplastic).

The term economic development (V85-Economic\_develop) showed implication in the reflection on social imbalance (V78-Social\_imbalance) and environmental imbalance (V25-Environ\_imbalance). Considering the generalized death conditions of biota and humans (V24-Death), factors such as pollution, oil, socio-environmental risks, marine animals, corals and fishing implied considering it as a result of the related variables.

On the influences of Cartesian (V83-Cartesian\_paradig) and systemic-complex (V84-Complex\_paradig) conceptions, defined by the number of relationships between concepts and correlated terms<sup>10</sup>, we could verify that the Cartesian paradigm (V83-Cartesian\_paradig) exclusively implied the theme of human consumerism (V35-Consum), as shown in Figure 7:

Figure 7: Partial view of the implicative graph of conceptual relations related to the Cartesian paradigm



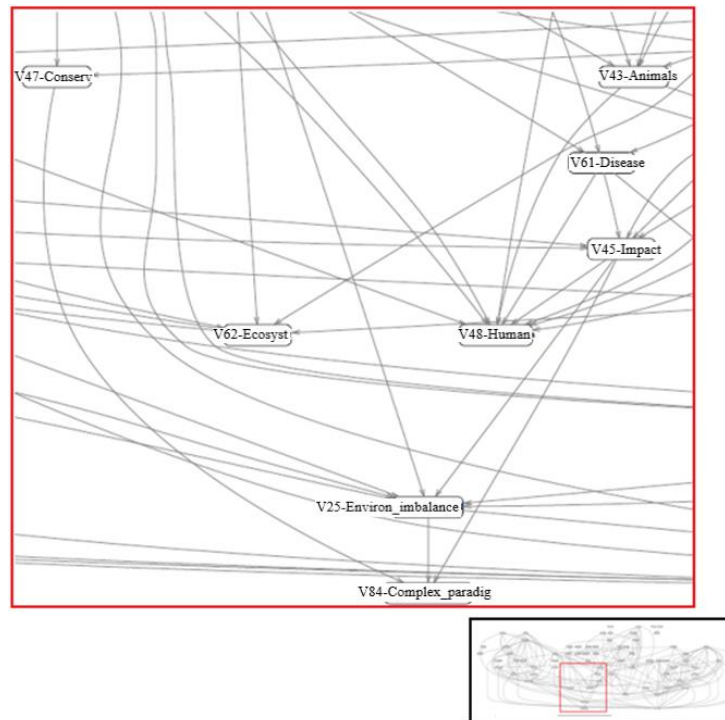
Source: Graph obtained through CHIC v. 7.0 software (2014) and adapted using Microsoft Paint3D. The red frame corresponds to the region of the implied graph under analysis.

Due to the complex nature of this study, it is worth explaining again what was presented in the methodology, that the implicative graph was obtained by analyzing all the chronicles. All the concepts were identified together and classified according to their paradigmatic nature. Thus, in the large implicative graph, the variables correspond to the concepts and their relationships and the paradigmatic nature of each chronicle is determined by the number of conceptual relationships in the texts.

In relation to the systemic-complex paradigm, there is an implicative phenomenon different from that observed in relation to Cartesian thought. While the Cartesian paradigm presented a unique implication regarding consumerism and garbage, the systemic-complex paradigm (V84-Complex\_paradig) was the result of implications of a larger and more diverse set of concepts, as can be seen in Figure 8.

<sup>10</sup> As mentioned in the methodology, up to five relationships were associated with the Cartesian paradigm, from this they were identified as influenced by the systemic-complex paradigmatic perspective.

Figure 8: Partial view of the implicative graph of conceptual relationships related to the systemic-complex paradigm



Source: Graph obtained through CHIC v. 7.0 software (2014) and adapted using Microsoft Paint3D. The red frame corresponds to the region of the implied graph under analysis. The variable (V84\_Parad\_Comp) is the last of the lower part.

Reflections on conservationism (V47-Conserv), environmental imbalance (V25-Environ\_imbalance) and environmental impact (V45-Impact) implied systemic-complex relationships (V84-Complex\_paradig). This can be justified by the complex nature of ecology when it addresses environmental issues, requiring holistic thinking linked to ecological relationships that require environmental conservation, or understanding of environmental imbalances resulting from factors impacting the environment.

Figure 7 shows that, despite the visual limitation, the concepts and related terms are connected by several vectors that start from them or arrive from other places. For example, the six vectors that arrive in the ecosystem variable (V62-Ecosyst) start from different concepts and terms, such as pollution belonging to marine biome, Atlantic Forest, Caatinga, soils, animals, anthropic action, among others. This means that to approach the concept of ecosystem requires a greater articulation of different concepts or terms.

The use of the SIA framework to investigate cognitive processes, scientific decisions and the philosophical-scientific foundations that structure thought has already been investigated by researchers such as Acioly-Régner and Régner (2005), Fazio and Spagnolo (2008), Di Paola and Spagnolo (2009), Pérez-Caraballo et al. (2012), Santos, Santos de Aquino and Ramos (2021) and Santos de Aquino (2022), only the last two of which relate the analysis of thought to the influences of scientific paradigms.

Acioly-Régner and Régner (2005) highlight the influence of the SIA framework on the identification of extra-school and school cultural knowledges occurring at the same time, in the process of interaction of different symbolic systems, revealing contrasts between everyday concepts (those from extra-school knowledge) and scientific concepts (from the school context).

Fazio and Spagnolo (2008) investigated the philosophical-methodological lines (constructivism, Aristotelian-Galilean and Platonist thinking) of undergraduate students on the

Secondary Education Teachers course at the University of Palermo, Italy. The authors found that the constructivist bases present in secondary and university education tend to influence the profile of future mathematics teachers, even if they study or carry out activities in other philosophical-methodological lines.

Di Paola and Spagnolo (2009), in turn, evaluated the way Chinese and Italian students think during mathematical learning, considering behavioral characteristics and strategies in solving mathematical problems. This study made it possible to identify certain characteristics and their tendencies according to the respective Italian and Chinese cultures.

Pérez-Caraballo, Acioly-Régner and Régner (2012), in a study in the field of psychology with individuals from international populations on the Brazil-Uruguay border, used the SIA framework to understand and analyze the prevalence of national identities to the detriment of border identities.

Santos, Santos de Aquino and Ramos (2021), in a study that aimed to identify the influence of scientific paradigms in the understanding of the Caatinga biome in secondary school, found that the traditional scientific paradigm constitutes the basis for the organization of the thought of secondary school students and that there are indications of expansion of conceptual relationships when school content is associated with the context of students' lives. In addition, the authors highlighted the importance of Environmental Education for the purposes of alleviated the effects of knowledge fragmentation in the educational field.

The study by Santos, Santos de Aquino and Ramos (2021) presents the effects of Cartesian structuring in secondary school that generate limitations to ecological understanding in a systemic-complex perspective. It is a representation of the Cartesian structure of Brazilian education and impacts the construction of meanings in Ecology. Although, these authors have not investigated teaching methodologies, but only the students' understanding of the Caatinga biome as a secondary school curriculum content, we can infer that this reverberates at other levels of education, such as college education and contributes to resistance of new didactic-pedagogical methodologies that aim to overcome traditional paradigms related to teaching practice, as well as in the construction of meanings of ecology that require greater cognitive effort in the articulation of concepts of areas traditionally considered distinct and isolated.

Santos de Aquino (2022), in his doctoral thesis, looked at the influence of the Cartesian, systemic and complex scientific paradigms on learning biochemistry, which was verified through an analysis of conceptual schemes in multilingual productions (drawings, diagrams, illustrated texts and poetry), according to the culture of the students (indigenous, quilombola, sertanejos and urban). The author identified through the theoretical-methodological integration of the ISA framework that culture and scientific paradigms imply different structuring of the way of thinking and learning and the materialization of learning.

We found that although Acioly-Régner and Régner (2005), Fazio and Spagnolo (2008), Di Paola and Spagnolo (2009) and Pérez-Caraballo, Acioly-Régner and Régner (2012) did not consider paradigmatic perspectives of science in their studies on cognition, indirectly the paradigmatic bases can be inferred and deduced in the context of the research. The studies by Santos, Santos de Aquino and Ramos (2021) and Santos de Aquino (2022) contribute directly to structuring a new methodological perspective on thought and its relationship with paradigmatic issues in science using the SIA framework.

In our study, we found that a curricular proposal of the discipline of Ecology Practice in higher education favored the construction of meanings in a systemic-complex perspective and

contributed to the reduction of paradigmatic limitations that reduce ecology to the natural environment including the human and social sciences in the process of construction of meanings.

## FINAL CONSIDERATIONS

The path that has brought us here helps us to understand a little more about the challenge of building meanings in ecology in the Biological Sciences degree, which we believe contribute to expand training towards a systemic-complex or simply ecological paradigm. Writing chronicles, in this process, seems to have the sense of an opportunity to establish relationships, not only between ecology and the concrete and complex situations of society, but also with the issues that touch and sensitize the licensees as authors of the word.

In general, we observed that the texts produced presented, in most cases, relationships influenced by the systemic-complex paradigm. This fact seems to be due, in a certain way, to the didactic-pedagogical and methodological option present in the curricular component, since the activity of writing chronicles, as a hybrid literary genre, produces a space of freedom for the author to establish relationships between different concepts and ecological themes.

On the other hand, the path also revealed that there is a tendency for students to resort to a Cartesian matrix thinking in certain themes, associating them mainly with the perspectives of radical and moderate ecology (JATOBÁ; CIDADE; VARGAS, 2009). Although this is a plausible interpretation in view of the context of a Biological Sciences course, it is still a result that needs to be scored and deserves to be questioned in the face of the desired ecological training in the context of initial teachers training.

Regarding the methodological tracing and the choice of a qualiquantitative approach, which combined the elaboration of conceptual schemes with the Implicative Statistical Analysis (ISA), we evaluated that they brought relevant contributions to the interpretation of the data, conferring a valuable materiality for the analysis of individual writing and as a whole, supporting each other basically qualitative and quantitative procedures as analytical and interpretative complements. In addition, mixed analytical models in which qualitative methods associated with quantitative ones are used and vice versa also approach the paradigmatic method of science in a complex perspective, which we learned from Morin (2002) is important for the construction of knowledge based on complexity.

Finally, we realize that this work contributes to the area of research in science and ecology teaching, at least for the following reasons:

(1) it combined qualitative and quantitative approaches to the research, giving the analysis a complex paradigmatic nature. In fact, the understanding of the whole from the integrated interpretation of its parts can make up the studies of the area, avoiding resorting to reductionist models that we usually criticize;

(2) the investigation of the construction of concepts in ecology contributes to the reflection on the need for an initial teacher training practice closer to reality and attentive to current demands since the purpose of teaching is not, and is not oblivious to, the purpose of learning and doing so in a complex way by dismantling Cartesian ties;

(3) the elaboration of conceptual schemes proved to be adequate to the investigative purposes of this work and its use associated with the Implicative Statistical Analysis (ISA) enhanced the identification of the construction of meanings under paradigmatic tendencies;

(4) certain ecological concepts and themes are influenced in a different way and this is verified

in the way the undergraduates have established more or less conceptual relationships according to the issues addressed.

Finally, we recommend that research into the relationship between scientific paradigms and cognitive processes be further developed in more studies that take into account the following perspectives:

- (1) different levels of education (basic, higher and post-graduate);
- (2) in teacher training;
- (3) in science teaching and education;
- (4) and innovative methodological perspectives with the development and popularization of SIA in education and science teaching research.

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#### **DECLARATION OF CONFLICT OF INTEREST**

The authors declare that there is no conflict of interest with this article.