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Flying Over the Scientific Community: The Semiotic Landscape in Science Education

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Abstract

This study, part of a doctoral research project, investigates the presence and influence of the main schools of semiotics (Prague, Paris and Australia) in doctoral research in the field of Science Education. Understanding semiotics as a relevant analytical approach for interpreting meaning-making processes, the aim was to map how these theoretical currents ground academic production. The methodology was based on cartography, conceived as a movement of flying over the scientific community, through a documentary analysis of doctoral theses available on the Oasisbr portal (2006–2022). Thirty-two theses were identified, 20 of which were grounded in the Paris school and 12 in the Australian school of Social Semiotics, with no records linked to the Prague school. The study contributes to understanding the semiotic landscape in Science Education and justifies the choice of Social Semiotics as the theoretical basis of the authors' doctoral research, strengthening the discussion on multimodality and its implications for teaching.

Keywords: Science education; Semiotics; Cartography; Multimodality.

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1. Introduction

In recent decades, Science Education has consolidated itself as a field of inquiry marked by a diversity of theoretical and methodological perspectives. In this scenario, semiotics emerges as an important line of analysis, since it makes it possible to understand how different modes, resources and representations contribute to meaning-making in educational processes. However, the plurality of semiotic schools, notably those of Prague, Paris and Australia, brings with it conceptual and terminological variations that sometimes generate ambiguities and misunderstandings in the use of theoretical frameworks.

In this context, the present study, part of a doctoral research project, seeks to map how the different currents of semiotics have permeated and grounded doctoral research in Science Education, based on scientific works available on the Oasisbr portal. The problem that drives us is to identify how these theoretical schools ground academic production, what distinctions emerge between them, and what implications these differences have for the research field.

Our aim, therefore, is to understand the semiotic landscape within Science Education, emphasizing the specificities of the three main schools and, in particular, justifying the choice of the Australian school of Social Semiotics as the theoretical foundation of the doctoral research of the authors of this article. The originality of the study lies both in the unprecedented mapping of academic production from this perspective and in the critical analysis of the theoretical influences that guide the field. By making this panorama explicit, we seek to contribute to conceptual clarity and to strengthening the theoretical grounding of future investigations, offering support for understanding and expanding the multimodal approach in Science Education studies.

2. Semiotic schools: The emergence of a theory

The development of a semiotic theory began in Europe, giving rise to three main schools: Prague, Paris and Australia. These schools drew on studies in Linguistics and adapted them to nonlinguistic modes of communication (Kress & van Leeuwen, 2006).

According to Kress and van Leeuwen (2006), the first of these is the Prague school (1930-1940), which carried out studies on art, theater, cinema and costume, building on the work of the Russian formalists. The second is the Paris school (1960-1970), which drew on Saussure's ideas to study painting, photography, fashion, cinema, music and comics. The term semiology is rooted in this school, together with the incorporation of other terms used by the American philosopher and semiotician Charles Sanders Peirce, such as signifier, signified, arbitrary and motivated signs, icons, indexes and symbols.

The third school, Social Semiotics, which began in Australia under poststructuralist influence, is based on Michael Halliday's ideas from Critical Linguistics (1970) and from the same author's Systemic Functional Linguistics (1980), applied to modes of representation (signifieds) with regard to the production of signs and their forms (signifiers) (Kress & van Leeuwen, 2006). In this school, the conception of the sign differs from that of the previous one, semiology, in which the sign is available to be chosen and used arbitrarily. Despite the differences in the definitions of certain terms stemming from these schools, Kress and van Leeuwen (2006) acknowledge the contribution of the other currents to the continuity of studies within Social Semiotics.

In Social Semiotics, the producer's interest in constructing meanings and new signs over the course of a process is intrinsic. This school marks the beginning of studies applied "[...] to multimodal texts by considering all the semiotic modes that accompany the verbal mode. It proposed a new approach, based on Halliday's (1985) conception, whose focus was centered on the social functions of language" (Quadros et al., 2018, p. 271, our translation).

Semiotics has studied signs since ancient Greece and today, as a transdisciplinary area, it is present in Psychology, culture, cartography, Linguistics, aesthetics, logic and religion, among other areas. The study of semiotics involves signs, sign systems and communicative processes, and applied semiotics involves the

contexts in which signs are used, as in medical, musical, film and visual semiotics. The latter, founded by structural linguists in the 1960s, studies still images as signs, that is, paintings, photographs and print media, among others, disregarding visually communicated signs such as geometry, writing and nonverbal communication (Nöth, 2013).

Visual semiotics also has schools that have influenced research trends, such as visual rhetoric and the Paris school. The former, according to Nöth (2013, p. 16, emphasis in original, our translation), was outlined by the "Liège Group (...), [which] postulates that paintings and other images can be studied by analogy with figurative language as derivations from *normal* images, which constitute a generic *zero degree* of visual communication", while in the latter images are studied by analogy with verbal language, at the levels of expression and content. Social Semiotics also addresses the image, for example in the book *Reading Images: The Grammar of Visual Design* (2006) by Kress and van Leeuwen.

Having briefly reviewed the history that inspired the development of a semiotic theory and the participation of important scholars who structured the three main schools of semiotics, we sought to map how these schools run through and influence doctoral studies. In doing so, we wish to understand how the schools differ from one another.

3. Flying over the scientific community in Science Education

To support the investigation in this study, we drew on the qualitative[1] cartographic method formulated by Gilles Deleuze and Félix Guattari (1995). Etymologically, the word cartography refers to the study of geographic charts, and in Geography it is the science that studies the description of maps[2].

From the perspective of the aforementioned authors, cartography connects rhizomes or networks and is constituted by a number of principles. The first and second principles refer to connection and heterogeneity, so that "[...] any point of a rhizome can be connected to any other, and must be" (Deleuze & Guattari, 1995, p. 14, our translation). The third, multiplicity, is defined by lines of deterritorialization, that is, ways of expanding a territory; the fourth, asignifying rupture, implies allowing ruptures in the rhizome, which is taken up again and reconstructed by other lines through movements of deterritorialization and reterritorialization.

Next, in the fifth and sixth principles, cartography and decalcomania, the rhizome is understood as a map that "[...] is open, connectable in all its dimensions, dismantlable, reversible, and susceptible to constant modification" (Deleuze & Guattari, 1995, p. 21, our translation). When we think of this reality to be mapped, there is no single direction, nor even a single entry into it; therefore, the methodological direction takes on an experimental character, in the sense that one moves in search of goals that are not predetermined, relying only on the attitude and intervention of the researcher.

Accordingly, the scientific community in Science Education, represented by the scientific works on the Oasisbr portal, constituted a map, a rhizome, a continuous region of intensities, plateaus, just as reality can be seen as a mobile map made up of meanings, knowledges and powers.

From the desire to fly over this map, we felt moved to learn about the three main schools of semiotics (Prague, Paris and Australia) and their representatives, and also to analyze how they run through and ground doctoral research. From this study, we understood the distinctions and particularities that cut across these theoretical currents and that can sometimes lead to misunderstandings of certain terms and concepts, in addition to their influence on scientific research. This strengthened our choice of the theoretical current adopted in our doctoral research, the Australian school of Social Semiotics.

[1] According to Passos, Kastrup and Escóssia (2012), quantitative studies may use the cartographic method, provided that they remain open to following processes.

[2] For more information, see <https://www.dicio.com.br/cartografia/>.

3.1. Scientific community: The semiotic approach in theses

In a cartographic movement, we will fly over the scientific community in order to identify the theoretical choices made by researchers in scientific publications in Brazil and Portugal. We used the Brazilian Portal of Open Access Scientific Publications and Data (Oasisbr[3]), an initiative of the Brazilian Institute of Information in Science and Technology (IBICT), which gathers multidisciplinary works and research data published in scientific journals, repositories and digital libraries, giving visibility and access to scientific content produced by researchers at Brazilian and Portuguese institutions.

In our research, the document type adopted was the doctoral thesis, and in the advanced search we selected the words Semiótica (Semiotics), Educação em Ciências (Science Education) and Ensino de Ciências (Science Teaching)[4] in all fields (title, author, subject, area, ISBN/ISSN, publisher, collection, year of publication and table of contents) between 2006[5] and 2022. We reached a total of 141 works and, after careful reading of the title, abstract and, in some cases, the theoretical framework and methodology (when not reported in the abstract), we ended with a total of 32 doctoral works, which we then described in terms of aim, methodology and results, identifying the semiotic school that ran through them. We note that we faithfully followed the wording of the terms and concepts used by the researchers in their theses.

In Annex 1, to situate the reader, we present a brief identification of these works in chronological order by year of defense. The description of the 32 theses in one of the sections of this text follows the presentation of the three main semiotic schools: Prague, Paris and Australia. Finally, we focus on the Australian school of Social Semiotics, the theoretical choice we adopted to support the doctoral research throughout its course. This choice is justified by the dialogical approach adopted by one of the first authors we consulted, Gordon Wells, who at times refers to the studies of Jay Lemke, also influenced by this school, who in turn leads us to Gunther Kress, one of the main scholars of the theory. It is in this last section, a dialogue with some of the works and a defense of our field of study, that the cartographic movement with the territory is carried out.

Next, we present the 32 theses (Annex 1), organized according to the semiotic school identified. To keep the reader informed of what they address, we provide a brief description covering the aim, methodology and results of each study. We highlight that 20 studies were identified as grounded in authors of the Paris school, while 12 were grounded in the Australian school of Social Semiotics. No work was identified with the Prague school.

3.2. Paris school

The first three theses presented in this section are grounded in the studies of the linguist Algirdas Julien Greimas[6], who, "[...] drawing on a structurally based theory of language, in addition to other sources such as phenomenology and anthropology, (...) builds an extremely cohesive and complex discipline, capable of examining the production of meaning in any text, whether verbal, nonverbal or syncretic" (Mendes, 2011, p. 174, our translation). In the thesis *Astros do rock: uma perspectiva sociocultural no uso da canção na Educação em Ciências*, Gomes (2016) starts from the argument that some rock songs from the 1960s and 1970s allow reflection at the conceptual, epistemological and sociopolitical levels on science, technology and their relationship with the environment and society, especially regarding astronomy. Having selected a number of songs, the author analyzed their content using semiodiscursive frameworks such as that of Greimas.

The activities of commented reading of the songs, with a critical discourse on science and its relationship with society and the environment, were directed both at higher education (students from different undergraduate and teacher education programs) and at secondary education, in natural science subjects and

[3] Available at <https://oasisbr.ibict.br/vufind/about/home>.

[4] In Biology, Physics, Chemistry and Science.

[5] The time frame marks the beginning of the regulation of distance higher education programs in Brazil, through Decree No. 5,773 of 2006.

[6] "It is with the work *Structural Semantics*, originally published in 1966, that Algirdas Julien Greimas (1917-1992), a Lithuanian linguist based in France, lays the foundations of what would later be known as Greimasian semiotics, the Paris School, or narrative or discourse semiotics" (Mendes, 2011, p. 184, our translation).

short courses, seeking to relate topics of modern and contemporary physics and to problematize the use of rock in Science Education. The results show that, although the songs speak of the past, they also evoke the present and the contemporary and thus explore a range of scientific topics, relying on the teacher's mediation, problematization and dialogicity.

In the thesis *Crise de identidade: gênero e Ciência nos quadrinhos de super-heróis*, Nascimento Júnior (2017) analyzes the influence of comic book culture on the gender identity formation of its consumers. With Greimas as the semiotic basis, the analysis seeks to understand the different representations of gender in this medium and their dialogue with science. The research began with a theoretical study of Cultural Studies and gender issues and a historical survey of the origins of the comic book culture of superheroes such as Superman and Wonder Woman. Workshops involving the use of comics were then planned and carried out in an elementary school. The results point to a solid relationship between gender representations and the predominant dissemination of male stereotypes of scientists in this culture. This conclusion stems from a binary interpretation of gender (male and female) and a set of values.

In Santos (2010), the thesis *Física no Ensino Fundamental: formação continuada de professores de Ciências em uma perspectiva sócio-histórica* presents a proposal for continuing education through an extension course for cycle II science teachers (physics in elementary school), grounded in Vygotsky's sociohistorical theory. The study addresses the need to analyze classroom activity from different angles, such as the conceptual one, the actions of teacher and student taken separately, and the social interactions present in the classroom environment. These discursive interactions were analyzed through Greimas's semiotics, and the results indicate that teachers in training, when they share experiences with their peers, advance in innovative practices, taking up new content arising from these formative experiences.

The next three works rely mainly on the framework of Raymond Duval[7], who built the theory of Registers of Semiotic Representation based on interpretations of the theories of Peirce, Saussure and Frege[8]. In the thesis *Produção de múltiplas representações semióticas para apropriação de conteúdos de Biologia celular no Ensino Médio*, Perucci (2020) investigates the alternation of multiple self-produced and canonical representations in a technical secondary school class. To this end, teaching units were designed to foster the production of representations, as well as the filming and narration of experiments. Perucci (2020) draws on Saussure's semiology to define the sign as a mutually dependent, arbitrary and unmotivated association between signifier (material portion) and signified (concept).

In addressing the multimodality that runs through different semiotic systems so that the appropriation of scientific concepts can take place, the author draws on Duval's conceptions, which, like Vygotsky's, consider mental representations to be connected with the internalization of verbal language, which constitutes a type of semiotic representation. Such representations are conscious and external and are recorded in signifying variables, each with its own association and modes of association, recalling Saussure's syntagmatic and paradigmatic categories[9].

Perucci (2020) stresses the use of multimodality in the production of self-produced and canonical representations in situations involving the production and interpretation of still and moving images, as well as verbal and visual analogies. The results show that an environment with greater freedom to produce records, through activities that explore multimodality, makes it easier to obtain idiosyncratic expressions, revealing to the teacher important information about students' appropriation of concepts.

Andrade Filho (2020), in the thesis *Sequência didática envolvendo modelagem matemática de transformações gasosas: concepção, execução e análise de resultados orientada pela noção de conciliação*

[7] "Raymond Duval is a French philosopher and psychologist born in 1937. He carried out much of his work in Cognitive Psychology at the Institute for Research in Mathematics Education in Strasbourg, France, from 1970 to 1999" (Almeida & Silva, 2018, p. 704, our translation).

[8] Friedrich Ludwig Gottlob Frege (1848-1925) was a German mathematician, logician and philosopher.

[9] When these signs are expressed, their development follows the structuring axes of language, the paradigmatic and the syntagmatic, which allow linearity. The paradigmatic axis derives from possible mental associations of units of meaning, whereas the syntagmatic axis derives from the increase in units of meaning during speech (Perucci, 2020).

de metas, analyzed the design, implementation and results of a teaching sequence whose plan of action was the collaborative reconciliation of the goal of mathematically modeling gas transformations. To this end, several theories were mobilized: Duval's Registers of Semiotic Representation, Mathematical Modeling, Didactic Situations in the context of Mathematics Education, and Relevance and Goal Reconciliation in the context of the sciences and of language. The sequence was organized into three contexts dealing with isovolumetric, isobaric and isothermal transformations. In each phase, twenty second-year students of a technical secondary program in chemistry took part in stages of contextualization, experimentation and mathematical modeling. The evidence suggests that mobilizing different registers of semiotic representation of mathematical objects improved the design and implementation of the teaching sequence from the teacher's point of view and supported students' actions throughout the modeling stages.

In Boni's (2019) thesis, *Reestruturação do modelo de redescrição representacional para a categorização de níveis de explicitação de conhecimentos construídos por estudantes em aprendizagem de composição vetorial de forças*, the aim was to categorize the knowledge that secondary school students show regarding the vector composition of forces. Data analysis was based on written records and transcribed interviews with nine students who took part in the moments when the researcher carried out interventions in physics classes from the perspective of Representational Diversity.

Representational Diversity is a semiological line of research that brings together both the representational registers present in Duval's theory of Registers of Semiotic Representation and the representational forms and modes of frameworks that discuss multimodes and multiple representations. This line seeks to understand and stimulate the construction of the meanings of scientific and mathematical concepts expressed by students, in addition to contributing to the educational process at the instructional and cognitive levels. The results showed that lower levels of explicitness are identified in questions requiring mathematical procedures, while higher levels of explicitness depend on verbalization and on the coordination of different representations of the same concept.

The thesis *Produções escritas dos estudantes do Ensino Fundamental por troca de representação de um signo artístico: aplicação da ferramenta analítica de tipologias discursivas como indicadora da compreensão de sustentabilidade*, by Silva (2018), hypothesizes that semiotic elements drawn from Santaella's Discursive Typologies[10] and from the Categories of Comprehension of Prieto's semiology[11] (which draws on Saussure's semiology to explain signifier and signified), when transposed to the context of Science Education, can serve as an important analytical instrument.

The research consisted of creating a tool to apply and analyze whether there was comprehension based on the discursive typologies of description, narration or argumentation produced by students in the final years of elementary school. The results indicate that descriptive discourses show that students did not understand, narrative discourses show some understanding, and argumentative discourses show either understanding or misunderstanding. In light of this, the results indicate that the analytical tool not only helped identify the discourses produced by students but also allowed an analysis of their understanding of the topic of sustainability.

In the thesis *Composição química: estudos semióticos e psicológicos*, by Gonzalez (2016), the author analyzes how chemistry preservice teachers use the sign chemical composition in theoretical chemistry problems according to aspects defined by Umberto Eco's semiotics, how they use the same sign in theoretical problems according to aspects defined by the study of thought and language by Vygotsky and colleagues, and also how psychic processes take part in the interpretation and translation of empirical formulas when solving theoretical chemistry problems. The research data came from paper records and transcribed audio and video.

[10] Maria Lucia Santaella Braga is one of the main disseminators of semiotics and of Charles Peirce's thought in Brazil, with more than forty published books. She is a full professor at the Pontifical Catholic University of São Paulo (PUC-SP), holds a doctorate in Literary Theory from PUC-SP and a *livre-docência* in Communication Sciences from ECA/USP.

[11] Luis Jorge Prieto (1926-1996) was an Argentine linguist and semiotician who applied structuralist principles to the phonological and semantic study of social exchanges.

The results show that, when using the sign chemical composition in solving theoretical problems, the preservice teachers interpreted and translated the empirical formulas. The conceptual systems conveyed by the empirical formulas were marked by subjectivity resulting from socialization, education and development. Owing to the preservice teachers' difficulties in interpreting and translating the names of substances, the author points to the need to emphasize the teaching of chemical language in both initial and continuing education of chemistry teachers, with a didactic approach that values semantic, syntactic and psychological aspects in the appropriation of the sign chemical composition.

The next twelve theses are grounded in the contributions of Charles Sanders Peirce for the theoretical and methodological basis of their research, beginning with *Conceitos ecológicos estruturantes: investigando o pensamento de futuros professores de Ciências Biológicas*, in which Palhaci (2015) aims to investigate whether and how systemic thinking is formed among undergraduates in an initial teacher education program in Biological Sciences. To this end, the author examined how students expressed their thinking when agreeing or disagreeing with statements related to ecological knowledge and how they organized biological concepts of ecology in concept maps through the appropriation of structuring concepts. Data analysis drew on Peirce's semiotics, and the results led to the development of summary tables of meaning and of teaching strategies in the form of questions that present the structuring ecological concepts so as to elicit and support more systemic, less memorized and less fragmented thinking.

In *Formação de professores na área de Ciências da Natureza: análise de uma prática reflexiva no estágio supervisionado*, Borges (2010) seeks to examine how reflective models can be developed in initial teacher education based on reflection-in-action, looking for alternatives to technical rationalism. The researcher seeks to diagnose the indicators that strengthen teacher education for action that goes beyond the reproduction of idealized models and to identify the obstacles that hinder this construction. Transcripts of meetings and reports by preservice teachers were analyzed using Peirce's semiotics, and the results point to the importance of reflection in the planning and implementation of teaching, as well as to the relevance of the formation of scientific concepts.

The mechanisms used to promote collective reflection included studies based on subject-specific and pedagogical courses already taken, as well as the reading, discussion and analysis of texts that made up the teaching action itself. The collective teaching action consisted of the preservice teachers choosing theme-objects (ecology, cytology and living beings) and implementing a project in groups in different classes of a secondary school. Collective teaching action emerged as essential, since it fostered the exchange of experiences, reflection on the activities and a broader view of the process.

In the thesis *Perspectiva semiótica sobre o uso de imagens na aprendizagem significativa do conceito de Biotecnologia por alunos do Ensino Médio*, Klein (2011) problematizes the relationship between image codes and the process of constructing the meaning of the concept of biotechnology. In doing so, the author articulates Peirce's semiotic theory with the theory of Meaningful Learning as an analytical tool to identify elements present in the conceptualization and production of scientific meanings. The data come from nine students' records of their reading of images and concept maps about DNA, restriction enzymes, transgenics, cloning and biotechnology.

The results indicate that the maps analyzed show greater interaction between the scientific[12], evaluative[13] and descriptive[14] domains, with considerable exploration of the topic of biotechnology. In the reading of images, there was a greater concentration in the scientific domain. It was thus found that there is no dependence between levels and domains of meaning and that the meaning-making process is idiosyncratic. Klein (2011) considers that the role of the image in science discourse and teaching, through the image analysis

[12] "In the case of the scientific domain, this chain runs from the description of the scientific object to the explanation of processes and mechanisms related to biotechnology" (Klein, 2011, p. 86, our translation).

[13] "In the evaluative domain, the domains of meaning that the reader can address are limited to the socioeconomic, ethical-moral and environmental discussion of biotechnology" (Klein, 2011, p. 86, our translation).

[14] This refers to the primary, denotative description of the object (Klein, 2011).

instrument used, proves efficient in understanding how codes of the image mode are converted into the written verbal mode, or vice versa, and the implications for learning.

The thesis *Significados sistêmico-complexos mediados pela linguagem audiovisual: investigando os fatores bio-sócio-histórico-culturais que permeiam as interações entre "ser humano-ambiente-teia alimentar"*, by Macêdo (2019), investigates teachers' processes of interpreting and re-elaborating systemic-complex meanings regarding the bio-socio-historical-cultural factors of the human-environment-food web relationship, mediated by audiovisual language articulated with the Multiple Perspectives Model (MoMuP), in light of Peirce's semiotics. The theoretical framework draws on the paradigms of science (Cartesian, systemic and complex), the MoMuP, Peirce's semiotics and Systemic-Complex Meanings. Seven teachers took part in the research, and the data came from the following instruments: a conceptual kit for building Networked Conceptual Organizations (OCR), audiovisual productions, a questionnaire, a *PowerPoint* presentation on semiotics, interviews and lesson plans.

Regarding the OCRs, the first ones focus on sub- and microscopic biological relationships, with occasional sociohistorical and cultural issues; in the second OCRs, the biological relationships are more macroscopic, and there is greater dialogue among the research participants on bio-socio-historical-cultural issues. In the audiovisual productions, one shows content opposed to the consumption of *fast food*, and another a bio-socio-historical-cultural analysis of food and of power and hierarchy relations in the kitchen, as well as gender and hygiene issues. The questionnaire shows that most teachers use images and audiovisual material in their classes. Many of their interpretive answers show a transition between the levels of Firstness, Secondness and Thirdness.

In *Ensino de Biologia e Educação Ambiental: uma leitura peirceana das formas de relação dos animais humanos com os não humanos*, Rodrigues (2015) aims to learn about and identify the emotional, energetic and logical dynamic interpretants of the relationships between humans and animals, produced in a biology teaching process with an environmental approach interfacing with the foundations of Peirce's Normative Sciences: aesthetics, ethics and logic. Data were analyzed using Peirce's theory of interpretants, the Normative Sciences and Environmental Education, based on narratives, interviews and short films produced by secondary school students. The results show that teaching and learning that relate biology to environmental education updated signs, triggered new cognitive semioses and changed students' ideals of conduct, enabling new ways of feeling, thinking and acting.

In the thesis *Interpretação das gesticulações de estudantes no laboratório de Química baseada na semiótica de Peirce*, Salvadego (2015) seeks to interpret the meanings of students' gestures in the chemistry laboratory while they carry out an experiment. Based on the representational multimodality of Peirce's semiotic theory, the laboratory is an instructional space that fosters the construction of the meaning of concepts. Students' gestures help expand senses and thus construct meanings, and, if considered as signs in the semiotic process, they can be studied and analyzed. The research focuses on empirical activities carried out with second- and third-cycle students of a technical secondary program in chemistry; therefore, actions matter more than gestures, although actions can also be thought of as a temporal composition of gestures.

Gestures are thus primarily expressive before being communicative, that is, signs of a deliberately unintentional nature in the sender/receiver relationship. In the pedagogical sphere, gestures have two dimensions: a cognitive one, which helps learners build their thinking and develop meaning about what is being studied, and a formative assessment one, which constitutes a nonoral language through which the teacher appreciates the meaning of the knowledge being built by the student. The results point to the need to make pedagogical instruments such as those evaluated in this research better known, so that teaching and learning in the laboratory take place effectively and immediately.

In the thesis *Níveis interpretantes alcançados por estudantes de licenciatura em Ciências Biológicas acerca das estações do ano por meio da utilização da estratégia de diversidade representacional: uma leitura peirceana para sala de aula*, by Sanzovo (2017), the aim is to identify and qualify the interpretant

levels generated with the use of representational diversity regarding the seasons of the year, produced by eighteen preservice teachers in Biological Sciences. The analytical instrument used is based on a reformulation of Peirce's concept of interpretants that allows the teacher to qualify the scope of the meaning built by the preservice teachers.

The results show that, before this teaching strategy was used, students presented an Immediate Interpretant Level regarding the concept, with standardized answers memorized through confused representations. During the activities, the Energetic Dynamic Interpretant Level was observed in two students, that is, behaviors, attitudes, procedures and techniques chosen randomly and in advance. Of these two students, one presented the so-called Final Interpretant Level regarding the phenomenon, in which the dynamic interpretant levels are harmonized. With the use of Representational Diversity, a significant number of students showed a Logical Interpretant Level, rigidly structuring the meaning of the astronomical phenomenon. This points to the effectiveness of the analytical instrument as a tool to be used in the classroom, helping teachers follow the production and development of meanings acquired by students, and also as pedagogical support in lesson preparation and as teaching material.

In *Alfabetização visual como estratégia de Educação Ambiental sobre resíduo sólido doméstico: os interpretantes de Peirce na compreensão das representações de estudantes do Ensino Médio*, Silva (2013) seeks to identify the typical mode of generalization of secondary school students on the topic of household solid waste. Data were analyzed by introducing diagrammatic reasoning into an investigation in which students expressed themselves through verbal and pictorial language while going through a learning experience as part of environmental education content.

The theoretical and methodological framework was based on Peirce's semiotic theory. The results suggest that the work fostered reflection on an Environmental Education practice within science education that stimulates and fosters a critical awareness of the problem in question, revealing the conditions under which visual literacy is established.

The thesis *O discurso imagético no ensino de Física: gestos, materiais e seus significados na transposição do conhecimento científico*, by Santos (2019), aims to discuss the role of visual language in teachers' work in physics teaching, identifying and classifying the modes of visual representation used. The discussion draws on Peirce's semiotic theory to indicate ways of using image-based discourse, carrying out a visual semiotic analysis of physics lessons with the aim of contributing to research and practice in education. The results seek to justify the inclusion of visual language among the knowledge necessary for teacher education and to contribute to the use of Peirce's semiotics as an instrument for analyzing teaching practice.

Souza's (2012) thesis, *Estratégias de comunicação em Química como índices epistemológicos: análise semiótica das ilustrações presentes em livros didáticos ao longo do século XX*, aims to reconceptualize, based on Peirce, the different proposals for describing the chemist's activity and the teaching of chemistry, to characterize the strategies for communicating chemical knowledge used by authors of general chemistry textbooks, and to look for correlations between the profile of the representations investigated, the evolution of chemical knowledge and the different conceptions of this science.

Thirty-one works were analyzed, and different approaches to chemical knowledge were identified: from chemistry as a practical and applied science (early twentieth century), to the science of the invisible (from the 1950s onward), to the science of interfaces. This transition brings changes in the strategies for representing chemical content: from illustrations of apparatus and experiments, there was a shift away from descriptive aspects in favor of representations of atoms and molecules, which over the century have been built with elaborate graphic resources and semiotic strategies, with increasing iconicity. The 1980s were marked by a large number of illustrations of phenomena inaccessible to our senses and of applications of chemistry in everyday life. The author therefore argues that Peirce's semiotics is a promising line of research on discursive strategies and their implications for chemistry teaching.

In the thesis *Uma proposta de análise semiótica do processo de integração de múltiplas representações*, Silva (2016) seeks to develop a semiotic analysis tool based on Peirce's theory, particularly on the triadic perspective of the sign, Peirce's phenomenological categories (Firstness, Secondness and Thirdness), the distinctions between object (immediate and dynamic) and interpretant (immediate, dynamic and final), and the concept of semiosis (the action of the sign), for the processes of integration between representations that occur in teaching and learning situations. The tool was evaluated for its applicability, that is, its operational handling and complexity of understanding; for its coherence, a validation criterion given that its results should be consistent with the science education literature; and for its relevance, that is, its capacity to offer new information.

For this evaluation, two analyses were carried out: the first concerns an interview in which a preservice physics teacher uses representations in a simulation environment regarding the concept of inertia; the second, a re-reading of data from a study published in an international journal using the same theoretical framework. The conclusions state that the analysis tool is applicable, coherent and relevant, and the data analysis shows that the results are consistent with those found in the literature, adding a new analytical perspective for cognitive processes such as sense-making.

In the thesis *Mindware semiótico-comunicativo: campos conceituais no ensino de Física para deficientes visuais utilizando uma interface cérebro-computador*, by Viveiros (2013), the aim was to turn an interface into an assistive resource to facilitate conceptualization by people with physical and visual disabilities in physics classes. This technology was evaluated through the Theory of Conceptual Fields, taking into account, in the technical and operational analysis of the interface, aspects such as didactic configuration, cognitive ergonomics and cognitive neuroscience, as well as Peirce's semiotic theory.

The results show that the interface reaches the status of assistive technology for sensorimotor extension in controlling the robotic unit through thought in physics classes, ensuring the inclusion, accessibility and empowerment of people with visual and physical disabilities. Another result shows that the interface was functional for recording and monitoring neurocognitive functions in daily tasks, through the analysis of brain electrical activity via electroencephalography and brain rhythms, showing a predisposition to learning and providing mechanisms of cognitive embodiment.

The analysis of the didactic data reveals cognitive constructs specific to the teaching and learning of physics. These constructs make up a semiotic protocol for physics teaching, highlighting sensorimotor and cognitive characteristics suited to the cognitive profile for conceptual learning in the area. Seeking to understand neurocognitive functioning could contribute to the development of more efficient and effective educational strategies for people with or without special educational needs.

From the description of the twenty theses above, we found that ten focused on teacher education and the analysis of teaching practice, authored by Gomes (2016)[15], Santos (2010), Andrade Filho (2020)[16], Gonzalez (2016), Palhaci (2015), Borges (2010), Macêdo (2019), Sanzovo (2017), Santos (2019), Souza (2012) and Silva (2016), while Gomes (2016), Nascimento Júnior (2017), Perucci (2020), Andrade Filho (2020), Boni (2019), Silva (2018), Klein (2011), Rodrigues (2015), Salvadego (2015), Silva (2013), Souza (2012) and Viveiros (2013) focused on the study of activities carried out by basic education students. Another aspect worth mentioning is that Perucci's (2020) thesis draws not only on the Paris school of semiotics, represented by Saussure, but also on authors such as Kress, van Leeuwen and Jewitt, among others, who belong to Social Semiotics, in order to discuss the multimodal approach.

3.3. The Australian school and Social Semiotics

In this section we describe the twelve theses whose theoretical framework is grounded in the Social Semiotics school, although at certain points, in a minority of cases, we identified the concurrent use of influences from the Paris school, as in Fernandes (2019) and Freitas (2009). We also found that the theses by

[15] A thesis focusing on both teachers and students.
[16] A thesis focusing on both teachers and students.

Albuquerque (2018), Souza (2014), Ferry (2016), Silva (2017), Freitas (2009) and Netto (2015) focus on teacher education, whereas the theses by Fernandes (2019), Pontone Júnior (2016), Fernandes (2007), Bocanegra (2015), Gurgel (2010) and Silva (2020) focus on activities carried out by basic education students.

We therefore begin with Fernandes (2019) and the thesis *A semiótica no processo de ensino e aprendizagem de Química para surdos: um estudo na perspectiva da multimodalidade*, which seeks to understand how different semiotic modes facilitate deaf students' access to chemical knowledge. The investigation focused on the practices of teachers who teach chemistry to deaf students, and, with the data obtained at one of the schools, a multimodal analysis of a teaching episode was carried out. An interdependence of the modes of meaning production was found, and also that sign-terms corresponding to chemical terminology are scarce, which led the research to contribute to the development of a sign glossary to facilitate the work of teachers and educational interpreters. The research also developed a multimodal teaching sequence on energy, implemented in the second year of secondary school with two included deaf students, and its contributions and limitations were analyzed. The author stresses that good classroom communication for meaning-making needs to favor multiple modes and visual resources.

We note that, before bringing in authors belonging to this school and line of study, Fernandes (2019) draws on the theoretical approach defended by Charles Peirce and collaborators, such as Lúcia Santaella. She then presents the approach defended by authors such as Kress, Jewitt, Halliday and Lemke in discussing semiotic modes. The researcher highlights that Peirce offers theoretical potential for discussing representations of chemical knowledge and concept development, alluding to the level of Thirdness, while Social Semiotics serves to elucidate what is intrinsic to the interactions between modes, the processes of mediated representation and the contributions to chemistry teaching.

The thesis *Uma imagem vale mais com mil palavras: estudo sobre a produção de textos multimodais para o ensino do conceito de respiração pulmonar*, by Albuquerque (2018), highlights that multimodal texts are increasingly present in everyday life due to technological advances. However, their potential is not properly explored, especially in science teaching and learning, since teachers are often not equipped for the reading needed to understand and produce them. With the aim of investigating how knowledge about multimodality introduced into teacher education can contribute to reading and constructing multimodal texts for teaching human pulmonary respiration, an elective course called Multimodality in Science Education was developed for the chemistry and biological sciences teacher education programs. Four students took part in the course, which lasted eleven months.

Data analysis focused on the multimodal texts built by the students for video lessons on pulmonary respiration, on the video-recorded analysis of multimodal texts used in the video lessons, on the answers to an interview about the process of producing video lessons, on the production of a set of multimodal texts for teaching human pulmonary respiration, and on their validation in undergraduate classes. For this analysis, the categories of Kress and van Leeuwen's Grammar of Visual *Design* were used. The results show that bringing multimodality into text production, assessment and reading expanded the participants' capacity for representation and communication through the integration of different modes of language, enabling the construction of teaching material for the content mentioned above.

The thesis *Construção de modelos e mediação do conhecimento científico na formação inicial dos professores de Química: uma análise do processo de ensino da Termodinâmica*, by Souza (2014), seeks to examine the effects of modeling activities in the initial education of chemistry teachers as an incentive for a dynamic environment that values dialogic interactions and multimodal actions in the classroom. The preservice teachers were involved in the social construction of models to explain the energy involved in chemical transformations and, in the final assessment, were confronted with situations requiring them to think of ways to mediate knowledge with secondary school students.

The data came from written materials, notes from the researcher's participant observation and video recordings of the lessons. The analysis drew on contributions from Social Semiotics as represented by Kress,

concluding that addressing issues of social and semiotic mediation in the initial education of chemistry teachers fosters a better understanding of the possibilities for articulating scientific knowledge in the classroom, leading them to a critical understanding of the foundations and uses of teaching models.

In Pontone Júnior (2016), the thesis *Simulações e laboratórios virtuais como recursos mediacionais multimodais nas ações de um professor de Física* investigates how simulations and virtual laboratories are used by a physics teacher in teaching this subject. The research participants were students at a federal public technical secondary school. The data came from video recordings of a teaching sequence on waves. Among the theoretical frameworks, the multimodal approach of Social Semiotics was used in the analysis, helping to understand that the teacher is concerned with helping students interpret the signs that make up the didactic inscriptions[17] on the application screens, and that, in mediating students' interaction with simulations and virtual laboratories, an orchestration of communication modes takes place in explaining key concepts and didactic inscriptions. The final remarks indicate an investment in the phenomenological dimension of school physics, fostered by concepts and models through applications or experimental artifacts. These models and concepts are characterized as tools for understanding phenomena and not as the ultimate objects of the teaching activity.

The thesis *Análise estrutural e multimodal de analogias em uma sala de aula de Química*, by Ferry (2016), aimed to understand the relationships between the characteristics of the analogies built by a chemistry teacher and the expressive resources he used. Social Semiotics supports the assumption that the construction of analogies[18] in science classrooms involves the orchestration of multiple modes of communication. Data were generated from audio and video recordings of lessons at a private higher education institution, and the final remarks shed light on the articulation between structural and expressive aspects of the process of building analogies to share meanings when teaching chemistry.

In *Você vê essa adaptação? A aula de campo em Ciências entre o retórico e o empírico*, Fernandes's (2007) thesis aimed to investigate communicative interactions through semiotic modes between monitors and students during field classes, as well as the functions performed by the modes in the activities. The research participants were sixth-grade elementary school students who took part in three trips to study coastal ecosystems in the Ilha do Cardoso State Park (São Paulo). At one point, the author compares the specificities of the use of semiotic modes in field classes with their use in the classroom as described in the literature. To make these comparisons, the theoretical basis is Márquez[19], who brings together the perspective of classroom science teaching and the multimodality of Social Semiotics theory.

The analysis focused on the gestures and speech produced in the field classes. The monitor leads the field classes and produces most of the messages; his speech seeks to manage and control the construction of the scientific narrative. Since there is no material support for the use of images and written texts in the field, speech and gestures must fulfill the functions of those modes. Based on the so-called empirical reference framework, the difference between a field class and a class on school premises lies in the participants' involvement in the empirical world, as a referential basis for constructing representations and for the collective negotiation of meanings.

In the thesis *O processo de aprendizagem em práticas de ensino por investigação: interpretações a partir da abordagem fenomenológica e Semiótica Social*, Bocanegra (2015) aimed to analyze how participants express their learning of scientific content and relate it to socioscientific aspects present in the topics studied in the Technical-Scientific Projects (PTC) course. The data came from descriptions written by students at a

[17] "[...] inscriptions can be understood as nonverbal representations, made up of one or more signs, used to communicate information or abstract phenomena, or to organize data. The concept of didactic inscription generically designates objects such as photographs, tables, graphs, diagrams, flowcharts and equations" (Pontone Júnior, 2016, p. 40, our translation).

[18] "In our research, we used the Structure-Mapping Theory originally proposed by Dedre Gentner (Gentner, 1983; Gentner & Markman, 1997) (...) According to this theory, what distinguishes analogies from other kinds of comparison can be identified by mapping the similarities posited between relations in the familiar domain and in the little-known domain, also known, respectively, as the base and target domains" (Ferry, 2016, p. 50, our translation).

[19] Associate professor at the Universitat Autònoma de Barcelona, Facultat de Ciències de l'Educació.

public secondary school at different stages of the project, after which their perceptions of learning were gathered and analyzed.

The theoretical and methodological framework drew on Phenomenology and on the Social Semiotics of Halliday, Lemke and Hasan[20]. The results show that the students were protagonists of their learning through dialogue among themselves and with the teacher's support, and that motivation, dedication, attention and critical sense at each stage of the work were identified by the students as something that added value and motivated them to incorporate it into future projects.

In the thesis *Análise de diferentes modos de pensar e formas de falar o conceito de ácido/base em uma experiência socialmente situada vivenciada por licenciandos em Química*, Silva (2017) seeks to analyze different modes of sense and meaning associated with the acid/base concept. To this end, the characteristics of seven hairdressers belonging to the same community of practice were identified, and a semi-structured interview covered questions related to techniques and procedures involving the understanding of the concept of acid. Next, the semantic relationship between scientific terms and the everyday terms of these professionals was analyzed to understand this concept.

The second stage of the research consisted of developing a case study and a teaching sequence with chemistry preservice teachers. Here, the conceptual profile of acid/base substances was also analyzed in order to examine ways of thinking. In addition, the relationship between meanings and contexts was analyzed based on the Social Semiotics of Halliday and Lemke.

The results show that the meaning the hairdressers give to the concept of acid stems from utilitarian/pragmatic conceptions, that is, from their experience of the routine procedures carried out in the salon. In the academic sphere, ways of thinking are closer to scientifically accepted conceptions, such as the rationalist one, that is, a way of conceptualizing acid/base detached from a social context. However, when solving the case study, an encounter was observed between the different ways of thinking about the acid/base concept arising from specific contexts, so that the preservice teachers articulated scientific language with the specialized language of the community of practice.

In *Elementos de uma poética da Ciência: fundamentos teóricos e implicações para o ensino de Ciências*, Gurgel (2010) discussed the role of narratives in scientific thinking and in science teaching. First, the author carried out a historical review of research on teaching and learning to show that the epistemological dimension in the construction of knowledge is weakened by the understanding of semiotic and discursive aspects of classroom interactions. The discussion also turned to research on argumentation and to whether the models adopted are sufficient for understanding ways of thinking scientifically, especially when situations involving something new require new ways of arguing.

The reflections therefore turn to the field of the poetics of science. After analyzing some original scientific texts, it was found that the pattern of argumentation is linguistically characterized as narrative, leading the author to consider the role of narratives in human thought as a way of elaborating thinking. Semiotics in this work was guided by the studies of Jay Lemke. In the final stage of the research, a set of activities involving the written production of the genres letter and narrative was carried out with students in a physics course at a secondary school. The analysis of the scientific narratives shows that students produce them satisfactorily with regard to the organization of situations or events involving scientific knowledge, fulfilling their role in science learning.

The thesis *A escolarização dos conteúdos imagéticos da Biologia: um estudo das práticas de construção e execução de aulas pelo professor de Biologia*, by Freitas (2009), aims to understand the teacher's role in school practices of transmitting the image-based knowledge of the biological sciences. Data were collected by filming biology lessons in secondary school, copying material from books, notebooks and websites used in the observed lessons, and interviewing the school's teacher.

[20] Ruqaiya Hasan (1931-2015), born in India, was a linguist and university professor in Australia and one of the scholars of Systemic Functional Linguistics, together with her husband, Michael Halliday.

The analysis drew on semiotics and on the discourse analysis of Bernstein and Bakhtin, applied to written and printed image-texts and to other image-based representations related to the content taught. Semiotics was drawn from authors such as Lemke, Kress and van Leeuwen, who belong to Social Semiotics, indicating that the approach adopted in the investigation considers biology content as represented through multimodality. The analysis of the image as a sign was grounded in Santaella, in light of Peirce's ideas, which take the resemblance between the image sign and its object of reference as the cause of the polysemy of the concept of image.

The semiotic analysis shows that the teacher is the one who deciphers the images and the arbitrary and abstract codes of academic biology, and to do so uses different simultaneous semiotic resources, such as gestural, pictorial and verbal ones. The board is the main material resource. The teacher also brings in examples from his life experience to contextualize certain concepts and codes. However, in some cases there may be a still abstract reproduction without contextualization. In textbooks, images give the impression of relying on the teacher's mediating action, since they lack explanatory texts on how to use them. The researcher concludes that teachers need training both for the conceptual understanding of images and for their use in the classroom.

In the thesis *Encontro com saberes de Física em uma atividade usando a dança como artefato cultural*, Silva (2020) sought to analyze how the learning of general mechanics knowledge takes place in the first year of secondary school using dance as a cultural artifact. The specific aim of the research was to examine whether an activity of this kind updates students' perception of physics and dance. The research was developed from a project called “Physics and Dance” and involved thirteen students. The data came from a sociocultural interview, two diagnostic tests on students' knowledge, observation of interactions during the sessions and an individual interview with each student. The theoretical and methodological support was the Theory of Objectification proposed by Radford[21], which focuses on the semiotic approach, on the study of the sign in its social use, that is, on the analysis of classroom phenomena that, through teaching and learning activities, encompass processes of objectification (updating of knowledge) and subjectification (transformation of being).

The analysis focused on the semiotic elements in oral and written discourse (gestures, posture and intonation, among others), as well as in the dance movements performed by the students. The results show that, in the process of objectification, students used semiotic resources to express their knowledge, with a polysemy in the use of certain physics terms, such as the meanings of velocity and collision; in the process of subjectification, there was a change in students' perception of physics and dance. Dance came to be seen beyond the arts, with possibilities for articulating the two. The final remarks indicate that the learning that took place in the activities fostered an updating of knowledge in the classroom involving elements of human subjectivity, which runs counter to traditional teaching.

In the thesis *Complementaridade onda-partícula e emaranhamento quântico na formação de professores de Física segundo a perspectiva sociocultural*, Netto (2015) studies some concepts of quantum physics in physics teacher education and, to this end, carried out three studies: a pilot and two teaching interventions in an undergraduate modern and contemporary physics course. The theoretical framework adopted comes from the sociocultural perspective, more specifically Vygotsky's theory of mediation. At certain points, Netto (2015) also refers to Wertsch[22], who, aligned with the sociocultural current and a follower of Vygotsky's work, discusses semiotic mediation as one of the essential concepts for understanding the zone of proximal development[23] (ZPD).

[21] Luis Radford is a professor at the School of Education Sciences of Laurentian University, Canada.

[22] James Wertsch is a professor of sociocultural anthropology who studies national narratives and memories and collective memory and identity, especially in Russia and other countries of the former Soviet Union, as well as in the United States.

[23] “To explain psychological development, which can be characterized by a qualitative evolution in the ability to carry out certain tasks from one level of complexity to a higher one, Vygotsky introduced the concept of the Zone of Proximal Development (ZPD)” (Netto, 2015, p. 114, our translation).

The activities with the research participants involved theoretical presentations and computer simulation, which Netto (2015) recognizes as a semiotic device. To understand the extent to which actions mediated by the use of computer simulation promoted collaborative conceptual construction among the preservice teachers, the discourses were analyzed, showing that antagonistic views persisted in the explanatory models built, as well as classical notions in the attempt at a plausible explanation of the phenomenon.

Of the twelve theses described in this section, the last two, by Silva (2020) and Netto (2015), are theoretically grounded not in authors belonging to Social Semiotics, as in the other ten, but in theorists who seek approximations with this current. In Silva's (2020) thesis, Radford is the main theorist, and he draws on Lev Vygotsky's cultural-historical current. Although Vygotsky did not necessarily propose a semiotic theory, considered language the main and most powerful influence on communication and thought, and did not introduce the notion of multimodality as Social Semiotics authors did (Jewitt et al., 2016), we consider that Silva's (2020) work fits in this section, since Radford recognizes cultural semiotics as allowing the intervention of different signs such as gestures, words and rhythms, among others.

In Netto's (2015) doctoral research, the theoretical framework draws on authors such as Vygotsky and Wertsch, within the sociocultural approach, which sees human activity as mediated by material tools, by signs and by cultural practice. Human development follows from this, being influenced by mediators and constituted by cultural meaning as they are used, transformed and constructed (Ribas & Moura, 2006).

To conclude the study, in the next section we adopt and justify the theoretical choice of Social Semiotics with a focus on the multimodal approach. In a cartographic movement, we turn to some aspects of the twelve theses that caught our attention and helped us discern what we seek to understand as we inhabit the territory of *online* science teacher education.

4. Dialogue with the works: Choosing the multimodal approach of Social Semiotics as a field of study

Throughout this text we have briefly reviewed the schools that influenced semiotic studies, as well as doctoral research grounded in these schools. We now give special attention to Social Semiotics, the theoretical current we adopted in our doctoral research. It is represented by renowned scholars such as Michael Halliday, Gunther Kress, Jay Lemke, Theo van Leeuwen and Carey Jewitt, among others, who were first “introduced” to us through the theorist Gordon Wells.

Social Semiotics opens a new phase of studies, since meaning-making is analyzed as a process, a social construction, that is, it “[...] has to do with human semiosis as a social phenomenon in its origins, functions, contexts and effects” (Santos & Pimenta, 2014, p. 298, our translation). The focus is thus on meanings, taking into account the cultural and ideological context in which one is immersed.

The sign is produced from the producer's interest, as the producer chooses the most appropriate representation of what is to be signified. Santos and Pimenta (2014, p. 299, our translation) highlight that this formulation ensures “[...] a revealing difference between conventional semiotics and Social Semiotics, bringing the latter closer to readings of ideological and power processes”, that is, producers and interpreters of texts follow paths based on their interests and choices.

From the perspective of Social Semiotics, the text is seen as having a multimodal and socially assigned format, which involves representation and communication. The former is guided by the producer's interest and motivation, taking into account context and culture. The latter is a process in which a product is produced and interpreted at the same time. Communication is therefore a two-way street that depends not only on those who produce it but also on those who interpret it.

Given the possibility of producing meanings by considering a variety of modes and media available to sociocultural actors, the multimodal approach emerges as a field of study. It is within this approach that

semiotic modes such as image, speech, gesture and music, among others, are made possible by sensory modalities such as the visual, tactile, kinetic, gustatory and auditory, among others (Santos & Pimenta, 2014).

Although today it may be familiar and even obvious that communication is always multimodal, whether face-to-face or at a distance, historically verbal language, especially the written mode, received more attention than the multiplicity of other socially shaped resources for communication. Digital technologies have helped make visible that texts are multimodal and that language through speech and writing is no longer sufficient or the only means of expressing meaning (Adami, 2017).

By stating that "[...] the semiotic landscape (...) contributes essentially to the visibility of multimodality as a phenomenon of contemporary communication and to its usefulness as a notion that can account for contemporary meaning making", Adami (2017, p. 458) invites us to reflect on the texts we come into contact with every day, which combine colors, writing, sounds, images and *layout* and often prompt us to interact by assigning tasks to be completed, whether in *online* or *offline* environments. As a result, we produce our own texts, combine a range of modal options and explore new functions of language resources, such as *hyperlinks* and video calls, among others.

In light of the above on Social Semiotics theory and the description of the twelve theses in the previous section, six of them relied on it to investigate science teacher education: Albuquerque (2018), Souza (2014), Ferry (2016), Silva (2017), Freitas (2009) and Netto (2015). We perceive as characteristic of research grounded in this theory the concern with understanding the process of investigating, examining and analyzing a phenomenon from the researcher's perspective and as the aim of the research.

In these works, we found no focus on the analysis of Virtual Learning Environments (VLEs)[24], nor on semiotic work[25] as a perspective on how preservice teachers construct meanings about phenomena so that science learning can take place. However, we identified some approximations with our work in the theses by Albuquerque (2018), Souza (2014) and Netto (2015), the first two of which adopted the multimodal approach.

Another aspect emerging in some theses, focusing both on teacher education and on basic education students, is the study of the construction of explanatory models as a form of multimodal representation. Here we can add the semiotic work performed by the participants in this construction. Of note are Souza (2014), who brings modeling into the initial education of chemistry teachers to articulate scientific knowledge, and Netto (2015), with explanatory models built collaboratively by preservice physics teachers, managed through actions mediated by the use of simulators and by asking questions to explain a concept of quantum physics.

There is also Pontone Júnior (2016), who works with basic education students on models as tools for understanding phenomena, that is, not as a physical object but as a mediator that triggers other signs while being a material means, and Gurgel (2010), on understanding ways of thinking scientifically.

Among all the aspects raised in the theses, Albuquerque's (2018) comes closest to the phenomenon we study in our doctoral research, since it covers the study of the human body through multimodal representation and communication by preservice teachers. In our research, however, we open up the possibility of investigating semiotic work in the field of *online* science teacher education, that is, in the meaning-making processes of the participants belonging to this social community.

5. Annex 1

Identification of the works selected on the Oasisbr portal

Author	Title	Graduate program/university	Advisor	Year
José Artur	Você vê essa adaptação? A aula de campo	Programa de Pós-	Sílvia L. F.	2007

[24] Systems or software that bring together content, exercises and tools for online courses for a virtual community. Available at <https://tutormundi.com/blog/ambiente-virtual-de-aprendizagem/>.

[25] Kress (2010) and colleagues use this term for the combination of modes, each assumed to communicate a meaning, which together represent what one wishes to convey, that is, a semiosis.

Author	Title	Graduate program/university	Advisor	Year
Barroso Fernandes	em Ciências entre o retórico e o empírico	Graduação em Educação/Universidade de São Paulo	Trivelato	
Cláudia Avellar Freitas	A escolarização dos conteúdos imagéticos da Biologia: um estudo das práticas de construção e execução de aulas pelo professor de Biologia	Programa de Pós-Graduação em Educação/Universidade Federal de Minas Gerais	Isabel Cristina Alves da Silva Frade	2009
Emerson Izidoro dos Santos	Física no Ensino Fundamental: Formação continuada de professores de Ciências em uma perspectiva sócio-histórica	Programa de Pós-Graduação em Educação para a Ciência/Universidade Estadual Paulista	Alberto Gaspar	2010
Ivã Gurgel	Elementos de uma poética da Ciência: fundamentos teóricos e implicações para o ensino de Ciências	Programa de Pós-Graduação em Educação/Universidade de São Paulo	Maurício Pietrocola	2010
Juliane Cristina Fabre Borges	Formação de professores na área de Ciências da Natureza: análise de uma prática reflexiva no estágio supervisionado	Programa de Pós-Graduação em Educação para a Ciência/Universidade Estadual Paulista	Ana Maria de Andrade Caldeira	2010
Tânia Aparecida da Silva Klein	Perspectiva semiótica sobre o uso de imagens na aprendizagem significativa do conceito de Biotecnologia por alunos do Ensino Médio	Programa de Pós-Graduação em Ensino de Ciências e Educação Matemática/Universidade Estadual de Londrina	Carlos Eduardo Laburú	2011
Karina Aparecida de Freitas Dias de Souza	Estratégias de comunicação em Química como índices epistemológicos: análise semiótica das ilustrações presentes em livros didáticos ao longo do século XX	Programa de Pós-Graduação em Química/Universidade de São Paulo	Paulo Alves Porto	2012
Edval Rodrigues de Viveiros	Mindware semiótico-comunicativo: campos conceituais no ensino de Física para deficientes visuais utilizando uma interface cérebro-computador	Programa de Pós-Graduação em Educação para a Ciência/Universidade Estadual Paulista	Eder Pires de Camargo	2013
Patrícia de Oliveira Rosa da Silva	Alfabetização visual como estratégia de Educação Ambiental sobre resíduo sólido doméstico: os interpretantes de Peirce na compreensão das representações de estudantes do Ensino Médio	Programa de Pós-Graduação em Ensino de Ciências e Educação Matemática/Universidade Estadual de Londrina	Carlos Eduardo Laburú	2013
Vinícius Catão de Assis Souza	Construção de modelos e mediação do conhecimento científico na formação inicial dos professores de Química: uma análise do processo de ensino da Termodinâmica	Programa de Pós-Graduação em Educação/Universidade Federal de Minas Gerais	Orlando Gomes de Aguiar Júnior	2014
Adriana Ribeiro Ferreira Rodrigues	Ensino de Biologia e Educação Ambiental: uma leitura peirceana das formas de relação dos animais humanos com os não humanos	Programa de Pós-Graduação em Ensino de Ciências e Educação Matemática/Universidade Estadual de Londrina	Carlos Eduardo Laburú	2015
Carlos Henrique Bocanegra	O processo de aprendizagem em práticas de ensino por investigação: interpretações a partir da abordagem fenomenológica e semiótica social	Programa de Pós-Graduação em Educação para a Ciência/Universidade Estadual Paulista	Silvia Regina Quijadas Aro Zuliani	2015
Jader da Silva Netto	Complementaridade onda-partícula e emaranhamento quântico na formação de professores de Física segundo a perspectiva sociocultural	Programa de Pós-Graduação em Ensino de Física/Universidade Federal do Rio Grande do Sul	Fernanda Ostermann	2015
Talitha Placido	Conceitos ecológicos estruturantes:	Programa de Pós-	Ana Maria de	2015

Author	**Title**	**Graduate program/university**	**Advisor**	**Year**
Palhaci	investigando o pensamento de futuros professores de Ciências Biológicas	Graduação em Educação para a Ciência/Universidade Estadual Paulista	Andrade Caldeira	
Wanda Naves Cocco Salvadego	Interpretação das gesticulações de estudantes no laboratório de Química baseada na semiótica de Peirce	Programa de Pós-Graduação em Ensino de Ciências e Educação Matemática/Universidade Estadual de Londrina	Carlos Eduardo Laburú	2015
Alexandre da Silva Ferry	Análise estrutural e multimodal de analogias em uma sala de aula de Química	Programa de Pós-Graduação em Educação: Conhecimento e Inclusão Social/Universidade Federal de Minas Gerais	Helder de Figueirêdo e Paula	2016
Emerson Ferreira Gomes	Astros do rock: uma perspectiva sociocultural no uso da canção na Educação em Ciências	Programa de Pós-Graduação da Faculdade de Educação/Universidade de São Paulo	Luís Paulo de Carvalho Piassi	2016
Isadora Melo Gonzalez	Composição química: estudos semióticos e psicológicos	Programa de Pós-Graduação em Ensino, Filosofia e História das Ciências/Universidade Federal da Bahia	José Luis de Paula Barros Silva	2016
Marcus Vinícius Duarte Silva	Uma proposta de análise semiótica no processo de integração de múltiplas representações	Programa de Pós-Graduação em Educação/Universidade Federal de Minas Gerais	Rosária Justi	2016
Renato Pontone Junior	Simulações e laboratórios virtuais como recursos mediacionais multimodais nas ações de um professor de Física	Programa de Pós-Graduação em Educação: Conhecimento e Inclusão Social/Universidade Federal de Minas Gerais	Helder de Figueirêdo e Paula	2016
Daniel Trevisan Sanzovo	Níveis interpretantes alcançados por estudantes de licenciatura em Ciências Biológicas acerca das estações do ano por meio da utilização da estratégia de diversidade representacional: uma leitura peirceana para sala de aula	Programa de Pós-Graduação em Ensino de Ciências e Educação Matemática/Universidade Estadual de Londrina	Carlos Eduardo Laburú	2017
Flávia Cristiane Vieira da Silva	Análise de diferentes modos de pensar e formas de falar o conceito de ácido/base em uma experiência socialmente situada vivenciada por licenciandos em Química	Programa de Pós-Graduação em Ensino das Ciências/Universidade Federal Rural de Pernambuco	Edenia Maria Ribeiro do Amaral	2017
Francisco de Assis Nascimento Junior	Crise de identidade: Gênero e Ciência nos Quadrinhos de super-heróis	Programa de Pós-Graduação da Faculdade de Educação/Universidade de São Paulo	Luís Paulo de Carvalho Piassi	2017
Mariana Fernandes da Silva	Produções escritas dos estudantes do Ensino Fundamental por troca de representação de um signo artístico: aplicação da ferramenta analítica de tipologias discursivas como indicadora da compreensão de sustentabilidade	Programa de Pós-Graduação em Ensino de Ciências e Educação Matemática/Universidade Estadual de Londrina	Carlos Eduardo Laburú	2018
Tereza Cristina Cavalcanti de Albuquerque	Uma imagem vale mais com mil palavras: estudo sobre a produção de textos multimodais para o ensino do conceito de respiração pulmonar	Programa de Pós-Graduação em Ensino das Ciências/Universidade Federal Rural de	Ana Maria dos Anjos Carneiro-Leão	2018

Author	Title	Graduate program/university	Advisor	Year
		Pernambuco		
Alan Santos do Santos	O discurso imagético no ensino de Física: gestos, materiais e seus significados na transposição do conhecimento científico	Programa de Pós-Graduação em Ensino, Filosofia e História das Ciências/Universidade Federal da Bahia	Maria Cristina M. Penido	2019
Jomara Mendes Fernandes	A semiótica no processo de ensino e aprendizagem de Química para surdos: um estudo na perspectiva da multimodalidade	Programa de Pós-Graduação em Química/Universidade Federal de Juiz de Fora	Ivoni de Freitas Reis	2019
Keila Tatiana Boni	Reestruturação do modelo de redescrição representacional para a categorização de níveis de explicitação de conhecimentos construídos por estudantes em aprendizagem de composição vetorial de forças	Programa de Pós-Graduação em Ensino de Ciências e Educação Matemática/Universidade Estadual de Londrina	Carlos Eduardo Laburú	2019
Patrícia Barros de Macêdo	Significados sistêmico-complexos mediados pela linguagem audiovisual: investigando os fatores bio-sócio-histórico-culturais que permeiam as interações entre "ser humano-ambiente-teia alimentar"	Programa de Pós-Graduação em Ensino de Ciências e Matemática/Universidade Federal Rural de Pernambuco	Ana Maria dos Anjos Carneiro-Leão	2019
Bazilicio Manoel de Andrade Filho	Sequência didática envolvendo modelagem matemática de transformações gasosas: concepção, execução e análise de resultados orientada pela noção de conciliação de metas	Programa de Pós-Graduação em Ciências da Linguagem/Universidade do Sul de Santa Catarina	Fábio José Rauen	2020
Lucas Roberto Perucci	Produção de múltiplas representações semióticas para apropriação de conteúdos de Biologia celular no Ensino Médio	Programa de Pós-Graduação em Ensino de Ciências e Educação Matemática/Universidade Estadual de Londrina	Carlos Eduardo Laburú	2020
Ronaldo Conceição da Silva	Encontro com saberes de Física em uma atividade usando a dança como artefato cultural	Programa de Pós-Graduação em Educação/Universidade Federal de Mato Grosso do Sul	Shirley Takeco Gobara	2020

Source: Brazilian Portal of Open Access Scientific Publications and Data (Oasisbr), Brazilian Institute of Information in Science and Technology (IBICT).

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