

# The Choice of Research in Epistemology of Biology: Dialogue Between Monads of Research Professors

A Escolha da Pesquisa em Epistemologia da Biologia: Diálogo Entre Mônadas de Professores Pesquisadores

La Elección de la Investigación en Epistemología de la Biología: Diálogo Entre Mónadas de Profesores Investigadores

Maria Júlia Corazza,  Jéssica Laguilio Rodrigues,  e Lourdes Aparecida Della Justina 

## Abstract

The article has the objective of understanding, through monads, the interests, difficulties and motivations of research professors when carrying out investigations in the history and epistemology of biology, after studies and discussions carried out in the context of postgraduate studies. The data were constituted through the methodology of narrative research, using the questionnaire and narrative interviews as instruments. The results were presented through monads, constructed based on Walter Benjamin and their analysis made it possible to identify senses, meanings and emotions about the motivations, interests and difficulties in historical and epistemological research. Also were identified the implicit conceptions about science and their epistemology in the narratives of researcher professors. Between the conclusions, we contrast which reading the monads revealed that the affinity for the history and epistemology of biology emerged, for most narrators, during preparatory studies and postgraduate studies, despite considering it a challenging and often lonely work.

*Keywords:* history and philosophy of biology, Teacher Training, studies and research group, narrative interview, Walter Benjamin

## Resumo

O artigo tem o objetivo de compreender, por meio de mônadas, os interesses, dificuldades e motivações de professores pesquisadores ao realizarem investigações em história e epistemologia da biologia, após estudos e discussões realizadas no contexto da pós-graduação. Os dados foram constituídos por meio da metodologia de pesquisa narrativa, utilizando como instrumentos o questionário e entrevistas narrativas. Os resultados foram apresentados por meio de mônadas, construídas com base em Walter Benjamin e sua análise possibilitou identificar sentidos, significados e emoções acerca das motivações, interesses e dificuldades na pesquisa histórica e epistemológica. Foram também identificadas concepções implícitas de ciência e sua epistemologia nas narrativas dos professores pesquisadores. Dentre as conclusões, destacamos que a leitura das mônadas revelou que a afinidade pela história e epistemologia da biologia emergiu, para a maioria dos narradores, durante os estudos preparatórios e no decorrer da pós-graduação, apesar de considerarem um trabalho desafiador e muitas vezes solitário.

*Palavras-chave:* história e filosofia da biologia, Formação de Professores, grupos de estudos e pesquisa, entrevista narrativa, Walter Benjamin

## Resumen

El artículo tiene como objetivo comprender, a través de las mónadas, los intereses, dificultades y motivaciones de los profesores investigadores al realizar investigaciones en historia y epistemología de la biología, luego de estudios y discusiones realizados en el contexto de los estudios de posgrado. Los datos fueron constituidos a través de la metodología de investigación narrativa, utilizando como instrumentos el cuestionario y la entrevista narrativa. Los resultados fueron presentados a través de mónadas, construidas a partir de Walter Benjamin y su análisis permitió identificar sentidos, significados y emociones sobre las motivaciones, intereses y dificultades en la investigación histórica y epistemológica. También se identificaron concepciones implícitas de la ciencia y su epistemología en las narrativas de los profesores investigadores. Entre las conclusiones, destacamos que la lectura de las mónadas reveló que la afinidad por la historia y la epistemología de la biología surgió, para la mayoría de los narradores, durante los estudios preparatorios y durante los estudios de posgrado, a pesar de considerarlo un trabajo desafiante y muchas veces solitario.

*Palabras clave:* historia y filosofía de la biología, Formación de Profesores, grupos de estudio e investigación, entrevista narrativa, Walter Benjamin

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## Introduction

The need for the presence of approaches relating to the nature of science, including aspects of its history and epistemology, in teacher training courses and science teaching, has been debated in academia for a long time. These discussions have intensified since the last decades of the 20th century and subsequent years (Siqueira & Pinheiro, 2022; Silva, 2020; Rivero & Wamba, 2011; Cachapuz et al., 2004).

At the beginning of the first decade of the 21st century, Pietrocolla (2002, p. 1) states that it is “nothing new that teaching science is one of the most difficult tasks”, both in basic and higher education. “Students have difficulty understanding and applying scientific concepts”, and as a result, “scientific subjects negatively impact students’ school experience” (ibid). For the author, “teachers are still not clear about what prevents students from learning science”, with few of them “realizing that a large part of teaching problems are directly linked to the characteristics of the knowledge they intend to teach” (ibid). In other words, science teaching and learning situations in classrooms disregard the complex historical process of building scientific knowledge, the variety of methods used, and the personal, social and cultural factors that influence this production in each period.

These aspects of teaching contribute to teachers, educators and also the media propagating naive, intuitive images of empirical and inductive science, based on the stages of a universal method and, therefore, objective, true and neutral, without ideology. In this way, the idea is conveyed that scientific knowledge is produced in a cumulative, linear and independent manner from the historical and social context (Rivero & Wamba, 2011; Cachapuz et al., 2004; Pietrocolla, 2002).

Therefore, there is a need for scientific education that enables the development of personal and collective culture, a form of critical thinking “that allows citizens to interpret reality with rationality and freedom, and have arguments to make decisions” (Rivero & Wamba, 2011, p. 10). As advocated by Rivero and Wamba (2011) and also by Cachapuz et al. (2004), you have to educate yourself and, for that, train in science and about science.

Understanding science, about its nature, means understanding the internal and external factors that influence its development; the problems that instigate the investigations, that trigger their studies; the methods used at each historical moment to construct and validate their knowledge; the expected results; the benefits and consequences in society, that is, the implicit and explicit values of scientific activity; and their relations with technology and society (Justina, 2011; Cachapuz et al., 2004).

Furthermore, it is necessary to “understand the concepts that support it” (Andrade et al., 2008, p. 13). This means that each science has its epistemology, with an object of study and characteristics that are peculiar to them, making studies on their nature essential in undergraduate courses, and teacher trainers who will work in scientific education. The epistemology of biology, for example, implies “reflecting at the level of concepts, how these have been and continue to be reconstructed” (Mayr, 2005, 2008; Justina, 2011, p. 65).

Despite all the recommendations for the use of the epistemology of science in teaching, analyses of normative documents for Basic Education indicate an incipient mention of content contemplating the nature of science (Pinto & Silva, 2021). Likewise, CNE/CP Resolution No. 2/2019, which defined and instituted the new National Curricular Guidelines — DCN (2019) for teacher training and the current Common National Base for Basic Education Teacher Training — BNC-Formação (2019), do not present a significant approach to the History and Philosophy of Science (Siqueira & Pinheiro, 2022).

In the specific case of Degree courses in Biological Sciences, analyses developed by Delizoicov, Slongo and Hoffmann (2011), in 12 public, federal and state Universities, in the Southern region of Brazil, demonstrated that six of them did not include studies and discussions about History and Philosophy of Science. The remainder presented traces of these contents in subjects with a variety of nomenclatures and workloads, revealing ineffective teaching practices regarding the nature of scientific knowledge.

In recent years, with the restructuring of Pedagogical Projects, there have been inclusions of effective, elective subjects or elements of History and Philosophy of Science in the syllabi of other subjects in Science Degree courses at various higher education institutions in Brazil, as recorded by some research. Among these, Schwantes, Marinho and Arnt (2017) identified the presence of History and Philosophy of Science in the syllabuses of undergraduate science courses at the six federal universities in Rio Grande do Sul. However, according to the authors, the syllabuses of some Courses focus on theoretical aspects of understanding science, failing to make connections between the History and Philosophy of Science and teaching. In a similar research, carried out at the

11 federal universities of Minas Gerais, 41 pedagogical projects were analyzed, of which 39 presented elements about the nature of science in the syllabuses of Biological Science, Chemistry and Physics courses (Colósimo, 2022). The author identified the presence of teachers/researchers in the area of science education in the preparation of these 39 pedagogical projects and concluded that these courses seek to train teachers who reflect on the historical, philosophical and sociological aspects of science.

However, according to the research carried out by Hidalgo and Lorencini Jr. (2019, p. 106), despite the presence of History and Philosophy of Science subjects in the curricular matrices of the Biological Sciences course investigated, there was no evidence of “evidence of their influences on the epistemological resignification” of biological contents by those researched. In this study, the results indicated that teaching internships and extracurricular activities, such as participation in the Teaching Initiation Program — PIBID, were more efficient in this requirement.

Nevertheless, if, on the one hand, the history and epistemology of science are still incipient content in undergraduate courses in Biological Sciences, on the other hand, subjects and research subjects for master’s and doctoral degrees in postgraduate programs in Education in Biological Sciences have been constituted. Sciences (Souza et al., 2022; Damasio & Peduzzi, 2017; Marandino, 2002). Furthermore, they are one of the main topics discussed in some studies and research groups in this area (Lima et al., 2019).

From this perspective, the issue that guided this article came from the need to know the perceptions of research professors, and participants in our study groups, regarding the importance and challenges in investigations in the history and epistemology of biology. Given this context, the following research question arose: what do the investigated research professors say about the reasons, interests and difficulties in developing research in the history and epistemology of biology? Thus, the objective of this work was to understand these reflections based on monads identified in narratives of former research professors or participants in study groups and postgraduate programs in Science Education.

Inspired by Walter Benjamin, we chose the narrative, in the form of a monad, as a tool for analysis and interpretation, since it allows us to remember the experience acquired in the development of research in the history and epistemology of biology.

### **Narratives and Monads in Walter Benjamin**

Walter Benjamin (1892–1940) explains that narrative “flourished in an artisanal environment — in the countryside, at sea, in the city”, being “itself, in a certain sense, an artisanal form of communication”, which “imprints the narrator’s mark, like the potter’s hand in the clay of the pot” (Benjamin, 1987, p. 205). For this German-Jewish philosopher and sociologist, the concept of narrative is associated with experience, wisdom, the advice of elders, past stories from generation to generation and, therefore, the narrators’ ability to remember. Thus, wisdom comes from lived experiences and stories emerge from these.

The narrative experience, motivated by practical interest and good advice, was for a long time the main means of disseminating events because, like fables and fairy tales, “it was characterized by the absence of explanations, leaving the reader or listener to interpret what they heard or read” (Fernandes, 2019, p. 8).

In his analysis of Benjaminian thought, Galzerani (2002, p. 90) explains that remembrance enables contact with the lives of several generations “which are intertwined in different times and spaces”. The author adds that, for Benjamin, remembering means bringing the past, not just as a nostalgic memory of lived experiences, but to question the present in search of directions for the future, which implies “awakening” and “overcoming the dimension of dreams” (Galzerani, 2002, p. 90). In the same sense, Petrucci-Rosa et al. (2011, p. 146) describe that remembering can be understood as the possibility of giving new meaning to “one’s own experience through conscious and unconscious memories full of meanings, feelings and dreams”.

From the perspective of remembrance, we use the narrative interview methodology as a possibility to give new meaning to the experiences told by researchers, to reference the reasons, interests and difficulties in the line of investigation of history and epistemology of biology, for new constructions in the practice of research and pedagogical action. By resorting to Benjaminian essays, we seek in the potential of monads the art of identifying fragments of narratives, full of meanings.

According to Oliveira (2015, p. 448), the concept of monad was defined by the Italian philosopher Giordano Bruno (1548–1600) as a “simple and unique substance”. This concept was appropriated and complemented by Leibniz when describing, in Monadology, the monad as a substance without parts, which integrates compounds, being itself indivisible, and indissoluble (Leibniz, 2009). Furthermore, as the philosopher explains, “in each monad all the others are present without distinction” (Benjamin, 1984, p. 70). Based on this philosophy, Benjamin describes that the idea is a monad, and “this means, in short, that each idea contains the image of the world”. Therefore, the monad is nothing more than “the description of this abbreviated image of the world” (Benjamin, 1984, p. 70).

In this conceptual perspective, Ferreira and Reis (2012, p. 2) deduce that monads can be considered fragments of texts constituted by a set of ideas that are articulated to form a “complete and unique” whole, “so that this whole can also be told by one of its fragments.” In a Benjaminian narrative dimension, Petrucci-Rosa et al. (2011, p. 203) define monads as “fragments of stories that, together, narrate the situation of a time and a place”.

As the authors explain, these fragments are made up of small stories or chronicles that combine beginning and end, but without expressing a clear outcome, leaving the interpretation up to the reader. The monads written by Benjamin (1987) have the function of advising, of transmitting a utilitarian teaching or rule of life, not requiring explanations to deduce what is written.

These and other characteristics reveal the methodological potential of monads in narrative research. However, to identify them, the researcher must have the perception and sensitivity to extract meanings from the narratives, according to their research questions (Costa et al., 2021).

### **The Narrative Interview Methodology Through Benjaminian Monads**

The research work proposed here was carried out along the lines of qualitative research, using the construction of narrative monads, obtained through interviews, to create interpretations about the reasons and difficulties in developing research in the history and epistemology of biological science. In this sense, it can be said that the quality of this research was constituted by the fact that its investigative context cannot be analyzed in isolation (Flick, 2011; Petrucci-Rosa & Ramos, 2015).

The research work was carried out in the context of study and research groups, linked to Postgraduate programs in Science Education, with nine participating researchers, who were developing or had already defended research with an emphasis on the epistemology of biological science. The empirical research with these subjects was carried out upon acceptance of voluntary participation, with the signing of the Consent and Free Information Form — TCLE, after approval of the project by the Ethics Committee, with a certificate of presentation of ethical assessment — CAAE. Taking into account the data protection standards established by the Permanent Committee on Ethics in Research with Human Beings — COPEP do Brasil, we sought to preserve the anonymity of research participants, replacing their names with the following pseudonyms: Ana, Nádia, Dante, Eloá, Ema, Lara, Levi, Mário and Sofia.

It is worth highlighting that all participants in the interview worked as teachers in higher education (05), basic education (03), or in the evangelical pastoral ministry (01), and or were engaged in study groups and/or research on the history and epistemology of biology and its teaching.

The narrative interview was carried out with the help of platforms for synchronous meetings between the research proponents and each of the selected researchers, resulting in a total of nine interviews recorded through Google Meet and later transcribed using the Transkriptor software.

As a methodological strategy, we chose narrative investigation by enabling, through dialogues, participants to present their academic life stories, remembering why they chose the line of research in history and/or epistemology of biology, as well as knowledge acquired and investigative practices.

Initially, in the methodological journey, the transcriptions were reviewed and reconstituted into narratives, without losing the meanings and meanings expressed by the interlocutors. Then, the monads were obtained through textualization procedures with the production of a title and editing (Petrucci-Rosa & Ramos, 2015). To identify the monads, the criteria described by Silva et al. (2018, p. 85):

- i) the narrative must be told as something that has passed. From the Benjaminian perspective, the narrative is a reminiscence, therefore, its narration is a remembrance;
- ii) it is necessary to identify in the narrative the relevant meaning it carries, the perceptions, feelings and emotions that awaken in the narrator when telling the story;
- iii) the identified meaning must be in convergence with the researcher's research problem. Since the identified Monad needs to be an advise;
- iv) after identifying the Monad, the title is assigned. This must be directly linked to its meaning.

The presentation of monads for analysis follows an ordering of senses and meanings that are similar to facilitate understanding of what is narrated, without the intention of establishing categories. The establishment of this ordering took into account the meanings expressed in the fragments, constructed from writings recollecting episodes from his academic life, contemplating his interests and difficulties, conceptions and knowledge constructed in research in the history and/or epistemology of biology.

As explained by Silva et al. (2018, p. 86), “there is no specific number of Monads per narrative nor is there any concern with the extension of each Monad. What is relevant are the meanings they carry” and the interpretations put forward by the researcher. Regarding the first aspect, depending on the ability to recall facts, express knowledge, conceptions and also feelings and emotions identified by narrator researchers, more than one monad was identified in some narratives, some being longer than others. Regarding the second aspect, the authors add that a narrative can be interpreted in different ways by different people so that each of them can generate different monads.

Benjaminian monads, as already stated, are self-explanatory “enabling the reader to delve deeper into their meanings and freely interpret this advice” (Silva et al., 2018, p. 86). To achieve this, the monads must be placed together, in an organization that takes into account the meanings they express. Based on Benjamin, the methodology of Petrucci-Rosa and Ramos (2015, p. 148) recommends that monads be presented in “a single block of fragments, without prior characterization” and without classification or categorization, but with an organization in which the arrangements produce comprehension effects for readers.

The narratives produced from the interviews with the nine researchers enabled the construction of 14 monads, presented and discussed in the following section.

## Unveiling the Curtains and Stones Along the Way

### Monad 1: Significant Learning, Long Memory

Since high school, the subjects I performed best at school were Biology, Philosophy, and History. An episode that I keep in my memory is from the history of science when a teacher started the cell biology content and spoke about the clash between spontaneous generation and biogenesis. We created drawings of the experiments of Francesco Redi, Lazzaro Spallanzani and Pasteur. So, that's when I started to like biology because it involved the history of scientific knowledge. It was significant learning, which has a long memory. When I was an undergraduate, the history and philosophy of science discipline caught my attention and that was when I began to identify with the degree. We ended up studying this historical clash in this discipline and we saw that it wasn't something linear, like we study in high school, it's not something ready-made, but a clash that lasted almost two centuries. It was because of this and other disciplines and, especially, a group of professors who brought this more epistemological perspective on scientific knowledge, that I directed myself towards this line of research in epistemology.

*Ana*

### Monad 2: Things That Mark us

In the third year of my undergraduate course, I met a professor with whom I had conversations about her research in teaching and I started to like her. She introduced me to this part of research in the epistemology of science, showing articles on the concept of gene, on the history of this concept and inserted me into the research group on the history and epistemology of science. I decided to do my course completion work (TCC) on the history of the gene concept, with the guidance of this teacher. Afterward, I went for my master's degree with the concept of eugenics, always seeking this historical and epistemological part of knowledge. I was still completing my master's degree when, at ENPEC (National Meeting of Research in Science Teaching), I met a research professor from another program and institution and asked her to advise me on my doctorate. In this program, I had other wonderful people, all the doctorate professors. The selection test was very much about the history and epistemology of science, about the philosophers of science. So, these are things that mark us! *Eloá*

### Monad 3: Discovering the Taste

I wanted to do a master's degree, but it seemed far from my reality, because I lived 150 km from the city where I could do my postgraduate studies, and I worked 40 hours in the classroom. Then, I met a teacher who collected data for her master's research, in my Biology classes in high school. She told me about her research



into teacher training and I thought: “Guys, she’s living here, she’s doing it, so we can give it a try!” She introduced me to the mentor professor who worked with the epistemology of biology and was reading the book *The Century of the Gene* by Evelyn Fox Keller, about the concept of genes. She asked what I wanted to research and I replied that she had an affinity for genetics. So, I saw the possibility of doing research in the teaching of genetics. I’ve always really liked philosophy, but initially, the project was about teacher training. But when the advisor started talking about epistemology... So, I came into contact with epistemology by studying the bibliography recommended by the program, and I said: “If I could combine epistemology with genetics...”. And the advisor said: “If you’re up for it, I’ll come along”. I remember that when we did the questionnaire, it was already all epistemological! *Nádia*

#### **Monad 4: Research, Study, be More Interested in What you Don’t Know**

I had a professor in my undergraduate degree who always said something that inspired me when choosing a topic for my doctoral research: “We have to research, study, and be more interested in what we don’t know than in what we already know”. I have always had difficulty understanding evolution, theories, and evolutionary dynamics. I remembered the names, as we see in the textbook, specific names of who did this or that, but the history of this whole process was very nebulous for me. This was an always recurring theme when I guided interns at PIBID and in the research group I participated in. I remember when the research professor, who later became my doctoral advisor, started her post-doctorate in the Postgraduate Program in Education at the institution where I worked and created a Community of Practice (CoP). At CoP, this professor presented the process of evolution, a little about epistemology, the history of evolution and biology itself as a whole; the importance of evolution within biology. This brought about this interest in knowing more, in going deeper, in researching more about the process of emancipation from biology and the role that evolution played in this process. *Levi*

#### **Monad 5: The Look Behind the Red Curtains**

I remember when the master’s notice came out, that the recommended literature presented, among other themes, “What is science” and “epistemology of science”. There were several recommended books and that was a shock for me because in my undergraduate studies, I did not have access to epistemology and the history of science. So, when I came across the literature for my master’s degree, the first impact was: “What is this?”; “What are you talking about?” I found a text by Roberto de Andrade Martins, which contained a little bit of each epistemologist. But it was still very abstract. The master’s courses allowed me to study each author in more

depth. It was amazing, because I had misconceptions about science, thinking it was neutral, that it didn't involve collaboration with other people. So, the vision of each epistemologist helped me build this greater understanding. Afterward, the study of the construction of biology also helped with this understanding: "It's not like that, this concept wasn't born ready-made, there was a debate, there were controversies". In my research, I had access to Robert Hooke's original book. I could see how in the textbook the historical episode of the discovery of the cell is described in a mystified and trivialized way! So, epistemology for me was a gateway to "looking behind the red curtains". Because what is behind is brought to us, in conventional teaching, as in a show, we end up not seeing much of the debate, the controversies, or everything that happens in the process of building science. During my doctorate, I was looking for work and ended up dedicating myself, perhaps, less to the history of science and more to the epistemology of biological classification. *Sofia*

### **Monad 6: The Contact With Epistemologists and the Beginning of Work in Epistemology**

It was during my master's degree that I took an epistemology course with a well-known researcher, in which we studied the main epistemologists. The discipline was quite dense, every week we studied a different epistemologist. We started with Kuhn, the following week it was Bachelard, the next week it was Fleck, then Feyerabend... It was very quick, but I learned a lot, especially by studying Steve French's book. From this discipline, I started working with epistemological issues. Kuhn and Fleck were the epistemologists I discussed most in my work over the last few years. The first work I published was about paradigms, hypotheses, discoveries, and teaching genetics in textbooks, which is what I studied in my master's degree. In it, I try to think about the issues of Mendelian laws as a paradigm in biology. It was from there that I began working in the field of epistemology, and since then I have worked a lot with these issues of paradigm, style of thought and collective thought. *Dante*

### **Monad 7: Taste for Philosophy and Evolutionary Narrative**

My degree was a bachelor's degree in Biological Sciences, but as I also always liked this philosophical field, I took another degree in theology. Within this perspective of historical and philosophical narrative, I became interested in the field of epistemology, mainly the narrative of biological evolution. For me, evolution permeates the areas of activity that I develop: biological, philosophical and theological. Epistemology brings the idea of going deeper into the process of building human knowledge, as well as its limits as knowledge, hence my interest in the master's degree in the area of Science Teaching. *Mário*

### **Monad 8: This is how I Started**

Besides biology, I liked history too. So, my advisor said: “Look, there is the area of history of science, the epistemology of science that you can work on, put things together and work with what you like”. That’s how I started working with the history of science involving genetics, involving philosophy and epistemology of science. As soon as I started, since graduation. *Lara*

### **Monad 9: It was a Process**

In my undergraduate studies I didn’t have an epistemology discipline, I ended up having access to these contents in my doctorate. My research project ended up taking a look at how the process of building knowledge about Down Syndrome occurred. There’s no way of knowing the decisive moment, I think it was a combination of conversations, guidance and disciplines that I took during my doctorate. It was in these moments that this idea of understanding the process of building this knowledge emerged; how it was established over time and think about how academics in the Biological Sciences course perceived this content and how they understood it. During the research project, Canguilhem emerged, as an epistemologist who brought a view to understanding the concepts of Down Syndrome. So, it was a process that epistemology ended up entering in this way, as things were being constructed. When I saw it I was involved in these epistemological and historical questions of science. *Emá*

### **Monad 10: Difficult Walk, but Rich in Learning**

My biggest difficulties were historical materials for the construction of that theoretical, historical and epistemological part of the research. The references that I had to study and analyze were old. Every time I read a book, I found an older one. But I was interested and looked for more of these references, also in other languages. That made it quite difficult. I also had difficulty accessing older literature and historical references. So, it was a matter of ‘mining’! These references helped me understand some points that were obscure in history and epistemology. The first practical challenge was understanding how I would carry out this research; and which instruments. Then another point was when I collected a truckload of data and didn’t know what to do with it. And yet another difficulty was studying and understanding Discursive Textual Analysis (DTA) to use in my research. *Levi*

### **Monad 11: Read and Reread**

When you enter the line of research in epistemology, you need a lot of reading. So, an initial difficulty I had was having patience and reading a lot. Because, whether you like it or not, you have to be patient, you have to read and re-read it several times. In some historical episodes, when reading some materials, they have to look for documents to understand the context of the time. Furthermore, when I started studying Dobzhansky, which is something more specific, I found it very difficult to find the original work. So, I think that having an online directory that brings together historical science documents would be a good way to overcome this difficulty. *Ana*

### **Monad 12: We see Everything Separated Into Little Boxes**

I had a lot of difficulty finding historical materials because there are articles, and books that talk more about the importance of the concept of genetic material and not about how it happened epistemologically, such as the concept of DNA. It was difficult for me to do the historical part, because, as there are several areas in biology, you finish the course without having extensive knowledge of them all. However, the guiding teacher directed me, giving me books so I could understand other concepts that were interconnected and not as separate as I thought. It was also a difficulty that I had, because we tend to do history linearly, and things happen at the same time, they are not in a straight line. So, understanding this and not trying to separate it into boxes was difficult, because when you leave high school and go to graduate school you see everything separated into boxes. And that's a hard barrier to break. *Lara*

### **Monad 13: There was a Lack of People From This Area**

One difficulty is the lack of people in this area. I found it difficult to find other students, and other people to talk to. For example, taking an epistemologist and applying it to biology, you couldn't find works on the internet by people who had done this, and you couldn't find people who were doing projects about this, among us. So, I felt alone and insecure as a student, not knowing if the way I was applying epistemology in biology was right. *Nádia*

### **Monad 14: Demarcation of Fields of Knowledge**

The challenge is to demarcate areas such as biotechnology and population genetics as a field of knowledge, and then work on issues of the history and epistemology of science. Population genetics is included in the textbook as if it were a sub-area of genetics, generally between evolution and genetics, and not as a field of

knowledge in its own right. It's the same thing with biotechnology. It is there in the final chapter of the genetics content. I have argued that they are fields of knowledge with their epistemologies, with their own history of the construction of scientific knowledge. *Dante*

### **Monad 15: It was a Very Vague Concept**

As I had never worked with epistemology or even the history of science, I had difficulty knowing and understanding the relationship between epistemology and science, in general, and biology. In my undergraduate studies, I did not have a specific epistemology course. So for me, at that time, it was a very vague concept. *Emma*

### **Monad Analysis: Motivations and Limitations**

The need for scientific education that enables students to interpret reality not only through concepts, laws, and procedures of science but also through its historical, philosophical, social and cultural aspects (Damasio & Peduzzi, 2017), has motivated the expansion of postgraduate, professional and academic programs in the area of Science Education in recent decades in Brazil. This fact has contributed to a growing volume of research and scientific production in this area (Santos et al., 2017; Delizoicov et al., 2013).

One of the lines of research that characterizes these courses is Epistemology of Science, also called History and Epistemology of Science, History and Philosophy of Science or even History, Philosophy/Epistemology and Sociology of Science, among others. These denominations also appear in these postgraduate courses and some undergraduate courses (Delizoicov et al., 2011), and are also mentioned in the narratives of the interviewed researchers who carried out or were carrying out research in History and/or Epistemology of Biology.

Although the term epistemology began to appear in the philosophical dictionary from the 19th century onwards (Pando & Almeida, 2021), its recognition as a scientific discipline is recent, which explains the memories expressed in the researchers' narratives, which situate the 'awakening' of interest in this line of research when studying these contents in depth during the doctorate (Monads 4 and 9); in conversations with a supervisor; studies for the selection and/or completion of History and Philosophy/Epistemology of Science subjects in the master's degree (Monads 1, 3, 5, 6 and 7); participation in study and research groups after the master's degree (Monad 4); during graduation through contact with research professors, participation in disciplines and study and research groups; carrying out scientific initiation projects (Monads 1, 2 and 8); degree in Theology (Monad 7). Among these, there was one whose interest in History and Philosophy arose in high school (Monad 1).

Some narrators (Monads 1, 3, 6 and 7) associate the interest in carrying out studies and research in the epistemology of biology with affinity with philosophy (Monads 3 and 7), history and philosophy (Monad 1) or with history (Monad 6). Regarding the relationship between the epistemology of science and philosophy, Japiassu (1991, p.23) describes that

[...] of epistemology we know a lot about what it is not, and little about what it is or becomes, since it is a recent discipline whose construction is, therefore, slow. Its status is far from being able to be well defined, both about the sciences, among which it intends to establish itself as an autonomous discipline, and about philosophy, from which it insists on separating itself without taking into account that one of its reasons for being is to postulate it as one of the fundamental requirements of any critical and reflective look at the sciences that are being created and transforming the world through the products that never cease to be launched in our culture.

When explaining this relationship, the author recalls that, traditionally, epistemology is considered a discipline within philosophy, since it was philosophers who carried out epistemological research on science, developing a philosophy of science. Nowadays, says Japiassu (1991), “it is scientists themselves who are interested in reflecting on what they do” (p. 30), asking about the problems, methods, and concepts of their disciplines; and knowledge began to be considered a process, provisional knowledge and no longer finished, definitive knowledge. In this sense, epistemology can be considered a discipline “whose essential function consists of subjecting the practice of scientists to reflection” that takes as its object “no longer an accomplished science, a true science”, but “the sciences in the process of becoming in its process of genesis, formation, and progressive structuring” (Japiassu, 1991, pp. 27–28). He further describes that “historicity is essential to the object of science on which a reflection that we can call “philosophy of science” or epistemology is established” (p. 31). Thus, like the epistemologist Bachelard, Japiassu understands epistemology as a philosophy of science, and considers the history of science to be a related discipline or even “one of the main functions of epistemology” (Japiassu, 1991, p. 31).

Similar conceptions about science and epistemology are contained in some narratives, even if implicitly, in the recollections about the genesis of interest and taste for this line of research. Enthusiasm for the history of science can arise in basic school when historical episodes are part of teaching activities, but only through epistemological studies does the understanding begin that scientific development is not linear, cumulative, and static (Monad 1). In this way, the historical and epistemological study on the formation and ruptures of concepts (Monad 2), the dialogue established with epistemologists, and reflections on reference science, enable the understanding that the construction of knowledge is not neutral and carried out by solitary geniuses, but it arises from debates and controversies existing between scientific communities, the emergence of epistemological obstacles over time, which limit and alter the course of its development (Monads 5 and 7).

When carrying out studies and research in history and epistemology we have to subject the reference science, its problems, its methods, and concepts to reflection, which requires an exhaustive search for theoretical references and readings to understand, problematize, and produce knowledge that can contribute to culture science, in general, for science teaching and teacher training. The difficulties highlighted, in most of the narratives, were precisely the need to read and re-read, the search and scarcity of literary materials, works and historical documents to understand the context of a given time. These narratives are represented here by the presentation of monads 10, 11, and 12. The difficulties in accessing historical materials are also reiterated by authors such as Martins (2005), Gandolfi and Figueroa (2017), in addition to Santos et al. (2018), who mainly reported the complexity of accessing original materials, such as primary sources, which are of academic relevance both for the development of research in the history of Sciences and in the epistemology of Sciences, as well as in their teaching. Gandolfi and Figueiroa (2017, p. 23), consider that

[...] amid the potential benefits that contact with historical-scientific texts can present for the training of Science teachers in different areas, this is not a simple job to carry out. Access to primary sources, even if recently facilitated by the free online availability of many of these materials, [...], still lacks a broad systematization and curatorial organization, which can make access difficult for teachers and teacher trainers with little or no prior training in historical research. Furthermore, not only access to these sources but also the work of historical-cultural contextualization and analysis and interpretation represent important steps that can constitute obstacles to this type of proposal.

Some narratives expressed difficulties in reading texts in other languages and/or in understanding historical and epistemological language (Monads 10, 12, and 15). Methodological difficulties were also reported by monad 10.

In her recollections of the time when she developed her master's epistemological research, Nádia, author of the narrative that made the construction of Monad 13 possible, expressed feelings and emotions of loneliness and insecurity triggered by the lack of colleagues who carried out work in this line of research in biology and other people, in addition to the supervisor, to discuss their data and results. This situation experienced by the narrator is consistent with data from 'state of the art' investigations that reveal the need for a greater number of academic research in the History and Philosophy of Science and its contribution to the teaching and training of teachers in biology (Augusto & Basílio, 2018; Santos et al., 2017).

Dante, the narrator who made it possible to construct Monad 14, did not express difficulties in carrying out the epistemological research he is carrying out, but feelings of challenge, in the sense of stimulating himself and the co-authors of his work, in demarcating, through history and epistemology of science, biotechnology and population genetics as fields of knowledge. This knowledge is recognized as subareas of genetics, being placed in separate sections or chapters in teaching textbooks, as explained by this

researcher and also by Caires Júnior and Andrade (2015), Leal and Barbosa (2016). These last two authors argue that the compartmentalization of biology content into volumes, chapters, and sections in textbooks gives rise to pedagogical gaps that make it difficult for students to learn. When analyzing materials from the third year, referring to genetics, Leal and Barbosa (2016) identified a predominance of content referring to Mendelian laws to the detriment of biotechnology, population genetics, and other subareas, which, together with fragmentation, prevents the intertwining of contents and understanding of biology as a homogeneous whole. In the same sense, Caires Júnior and Andrade (2015) consider that with this structuring there is a historical and conceptual separation of population genetics from the themes of biological evolution, making this content timeless.

Regarding the aspects mentioned, carrying out research in the history and philosophy of science can provide elements that contribute to overcoming this fragmented view of teaching, textbooks, the training of teachers and researchers in the biological area and the teaching of biology. Therefore, to train research teachers, studies, readings, and meeting epistemologists and authors in this area are necessary. Regarding this requirement, another aspect that stands out in the narratives, present in the set of monads, are the memories of theoretical references that were part of the readings and the elaboration of the projects, such as: the book *The Century of the Gene* by Evelyn Fox Keller, text by Roberto de Andrade Martins; book by Robert Hooke (*Micrographia*); book by Steve French (*Science: key concepts in Philosophy*); book by Thomas Kuhn (*The Structure of Scientific Revolutions*), original work by Dobzhansky (*Genetics and the Origin of Species*); methodology book (ATD) by Moraes and Galiazzi (*Discursive Textual Analysis*). Among the epistemologists, in addition to Thomas Kuhn, Paul Feyerabend, Stephen Toulmin, Gaston Bachelard, Ludwik Fleck, Georges Canguilhem and Ernest Mayr were also mentioned.

These recollections reiterate that there is a tradition in the disciplinary matrices that support learning in epistemology, in starting by studying the theories of the main epistemologists in the sciences.

## **Conclusions and Outlook**

This investigation, developed based on narrative research, made it possible to understand how historical and epistemological debates, promoted during undergraduate and/or postgraduate courses, research projects, orientations and study groups, contributed to motivating the development of research along these lines.

The monads, extracted from narrative interviews, were built to identify which interests motivated the research and the difficulties encountered. As the reading of the monads demonstrated, the understanding and affinity for the history and epistemology of biology were revealed and developed, by the majority of those interviewed, during their preparatory and postgraduate studies, which demonstrates that the undergraduate courses they took did not make an effective contribution in these aspects.



However, factors that limit research in this line were also pointed out, such as the lack of materials and the incipient number of researchers working with historical and epistemological elements of biology. As a result, research in history and epistemology becomes sometimes challenging and lonely work.

The monads revealed that engaging in this line of research was a process of uncovering an understanding of the context, behind the scenes and integrations between different areas of knowledge for the construction of scientific knowledge. In this sense, the need and relevance of spaces for dialogue, greater availability and access to materials, including primary sources, that cover the history and epistemology of biology, in specific disciplines, an integral part of other disciplines and study groups and research in the initial training of teachers and researchers.

The constructed monads made it possible to extract senses, meanings, feelings and emotions remembered about the history and epistemology of biology. Thus, knowledge and understanding about the theoretical references used, concepts and theories investigated, and implicit conceptions of science and epistemology were captured in small fragments.

In this panorama, although we are beginning studies with the use of monads, we consider that these are a prominent methodological tool for qualitative research, through narratives, in science and biology teaching.

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 **Maria Júlia Corazza**

Universidade Estadual de Maringá  
Maringá, Paraná, Brasil  
mjcorazza@gmail.com

 **Jéssica Laguilio Rodrigues**

Universidade Estadual de Maringá  
Maringá, Paraná, Brasil  
jessica\_laguilio@hotmail.com

 **Lourdes Aparecida Della Justina**

Universidade Estadual do Oeste do Paraná  
Cascavel, Paraná, Brasil  
lourdesjustina@gmail.com

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Alice Alexandre Pagan

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