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PRACTICAL ACTIVITIES OF SCIENCE AND TEACHER EDUCATION: AN ANALYSIS BASED ON TEACHING KNOWLEDGE AND THE BIOLOGY OF COGNITION

ATIVIDADES PRÁTICAS DE CIÊNCIAS E FORMAÇÃO DE PROFESSORES: UMA ANÁLISE FUNDAMENTADA NOS SABERES DOCENTES E NA BIOLOGIA DA COGNIÇÃO

ACTIVIDADES PRÁCTICAS DE CIENCIA Y FORMACIÓN DEL PROFESORADO: UN ANÁLISIS BASADO EN EL CONOCIMIENTO DOCENTE Y LA BIOLOGÍA DE LA COGNICIÓN

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ABSTRACT: In this work we sought to discuss the results obtained in research that focused on practical activities and teaching knowledge in the continuing education of teachers, taking as a reference another theoretical perspective, the biology of cognition. The objective of the analysis was to evaluate whether theoretical triangulation makes it possible to expand the interpretation and give new meanings to the empirical data produced in the investigation. To this end, some practical activities were selected and analyzes were carried out based on the theory of teaching knowledge. Subsequently, taking as a reference some structuring categories of the biology of cognition, a new interpretation of the data was made. The analysis suggests that even though the research object is viscerally linked to theory, it can be taken in an expanded sense, requiring analysis based on other theoretical references. The importance of Humberto Maturana's construct, the biology of cognition, for the continued training of biology teachers is also highlighted, as it contributes to expanding and reformulating knowledge already acquired.

KEYWORDS: Science teaching. Continuing training. Teaching knowledge. Biology of cognition.

RESUMO: *Neste trabalho buscou-se discutir os resultados obtidos numa pesquisa que tematizou atividades práticas e saberes docentes na formação continuada de professores, tomando como referência outra perspectiva teórica, a biologia da cognição. Com a análise, objetivou-se avaliar se a triangulação teórica possibilita ampliar a interpretação e dar novos significados aos dados empíricos produzidos na investigação. Para tanto, selecionou-se algumas atividades práticas e as análises feitas a partir da teoria sobre saberes docentes. Na sequência, tomando como referência algumas categorias estruturantes da biologia da cognição fez-se uma nova interpretação dos dados. A análise sugere que mesmo o objeto de pesquisa estando visceralmente ligado à teoria, pode ser tomado num sentido ampliado, cabendo uma análise a partir de outras referências teóricas. Destaca-se, também, a importância do constructo de Humberto Maturana, a biologia da cognição, para formação continuada de professores de biologia, pois contribui para ampliar e reformular conhecimentos já adquiridos.*

PALAVRAS-CHAVE: *Ensino de ciências. Formação continuada. Saberes docentes. Biologia da cognição.*

RESUMEN: *En este trabajo buscamos discutir los resultados obtenidos en una investigación que se centró en las actividades prácticas y la enseñanza del conocimiento en la formación continua de docentes, tomando como referencia otra perspectiva teórica, la biología de la cognición. El objetivo del análisis fue evaluar si la triangulación teórica permite ampliar la interpretación y dar nuevos significados a los datos empíricos producidos en la investigación. Para ello se seleccionaron algunas actividades prácticas y se realizaron análisis basados en la teoría de la enseñanza del conocimiento. Posteriormente, tomando como referencia algunas categorías estructurantes de la biología de la cognición, se realizó una nueva interpretación de los datos. El análisis sugiere que, si bien el objeto de investigación está visceralmente vinculado a la teoría, éste puede ser tomado en un sentido ampliado, requiriendo un análisis basado en otros referentes teóricos. También se destaca la importancia del constructo de Humberto Maturana, la biología de la cognición, para la formación continua de profesores de biología, ya que contribuye a ampliar y reformular conocimientos ya adquiridos.*

PALABRAS CLAVE: *Enseñanza de las ciencias. Formación continua. Conocimientos docentes. Biología de la cognición.*

Introduction

Research in the area of education, especially those dealing with science teaching, is justified, among other aspects, by the low performance of basic education students. The works focus on at least one of the countless variables that condition educational practice. It is noteworthy that, even recognizing the complexity that involves the practice, the researcher, to carry out the work, which also has its constraints, needs to delimit its object of investigation. Therefore, this article intends to discuss a work whose object articulated two variables, which are: teacher training and methodology, or rather, a methodological procedure used in the area of science teaching, practical activities (PA).

From this perspective, based on dialogue with works that focused on practical activities and teacher training, the following research question was formulated: a process of continued training, centered on practical activities, can contribute to (re)construction and mobilization of teaching knowledge? The sections that deal with the methodological path and some of the dialogue carried out with theories involving practical activities and teaching knowledge, in the area of science teaching, will provide the context that led to the formulation of the research object. By bringing the context, aspects that justify the importance of this work are also highlighted.

It is worth noting that in the research process, from the production and analysis of data, we sought to answer the question posed. Furthermore, this article proposes to interpret the data produced from another theoretical perspective, the biology of cognition, aiming to verify whether this triangulation allows new assertions of knowledge, in terms of problems and conjectures.

Thus, in an attempt to give clarity to the text, the results and discussion will initially be presented based on theorizations about practical activities in science teaching and teacher training models, with an emphasis on the theoretical construct about teaching knowledge (Tardif, 2000). Subsequently, based on some relevant categories of the biology of cognition, the results will also be analyzed in light of this theoretical framework. The final considerations will highlight the extent to which the objectives were achieved and the importance of carrying out, within the teaching area, this type of reflection.

Methodological Path

The research used a qualitative approach (Bogdan; Biklen, 1994), with an increase in participant observation (Moreira, 2002) and with the assumptions of collaborative research (Ibiapina, 2008).

The empirical data were produced during the execution of the Dialogues on Teaching Natural Sciences project. The continuing education project had the participation of teachers from a state school in the interior of São Paulo, including a biology teacher (PB), a chemistry teacher (PQ), a physics teacher (PF) and a science (PC) and external collaborators (three researchers in the area of Science Education, one university professor, one doctoral student and one master's student) from a higher education institution in the same city.

The project took place over two consecutive years with fortnightly meetings. During the meetings, a provocative attitude was adopted regarding the demonstrative and experimental activities carried out (selected sometimes by teachers, sometimes by researchers), around which intense discussions arose, a procedure that proved to be important for data production. Between the fortnightly meetings, the researchers (external collaborators) held planning and discussion meetings on the activities already developed.

For the most part, research data was recorded through field notes (Bogdan; Biklen, 1994). At the end, a data CD was recorded with notes in chronological order of the meetings held and the analyzes were based on reading the field notes. The data collected constituted dense material, the analysis of which was carried out in the first author's thesis. To interpret the material, content analysis was used as a reference (Bardin, 2010). It is also noteworthy that the teachers involved signed a consent form for the use of information.

For this article, two practical activities carried out with teachers within the scope of the project were selected, the results of which were analyzed with reference to theories about AP and the construct about teaching knowledge. Then, the material will be interpreted from another theoretical perspective, the biology of cognition.

Theoretical contributions

This section will present the theoretical references used in the analysis and discussion of the data. Initially, it is necessary to bring the theoretical constructs that guided the construction of the research object and, also, the first analysis carried out based on the data produced in the investigation. Next, some categories will be presented from the other theoretical perspective that will be used to interpret the data.

Practical Activities and teacher training

There is a consensus in the area of science teaching that AP are important means of ensuring science learning, either because they generate motivation in children, or because they can guarantee student participation in investigative processes. In one way or another, practical activities are considered potential strategies for developing scientific knowledge about natural phenomena and also about scientific construction itself.

In the area of science teaching, there are different meanings of what AP is. In this article, Labarce's definition (2014, p. 16, our translation) is considered:

> Practical activities are teaching activities in which the student has physical, cognitive and emotional contact with the phenomena studied directly and not only through descriptions presented by the teacher. They can consist of simple observations of specimens, in investigative situations or even in carrying out experiments.

The author emphasizes that practical activities have a didactic-pedagogical purpose, so their structure is not necessarily similar to the observation and experimentation activities recorded in the History of Science. Therefore, the use of analogy, as recommended by the teaching area, implies an effort to distinguish, that is, to explain what differentiates them.

An important aspect of reflecting on practical activities is conceiving them as part of broader didactic strategies, which define their objectives and characteristics. For example, when a proposal is aimed at so-called traditional teaching, practical activities generally have the role of illustrating or confirming a theory; in the context of teaching through conceptual change, the activity must fulfill the role of generating cognitive conflict or confirming a new explanation, in the research-based teaching model, practice can function as one of the resources to involve students in investigative processes (Bastos *et al.*, 2004).

However, although the importance given to AP seems consensual (by teachers, students, literature) they are still not prioritized in most schools. This inconsistency is generated for different reasons (lack of resources and laboratories in schools, uncritical use of textbooks, lack of professional development policies, training gaps for science teachers, among others). Some researchers who dedicate themselves to the study of practical activities (for example: Labarce, 2014; Bassoli, 2014; Andrade; Massabni, 2011; Marandino, 2003; Borges, 2002; Praia; Cachapuz; Gil-Pérez, 2002; García Barros *et al.,* 1998; Hodson, 1990; Gil; Payá, 1988) are unanimous in reinforcing the epistemological and conceptual difficulties of teachers when it comes to using AP as part of their teaching process.

In this sense, bringing AP into the teacher training process can help in understanding the real possibilities of its use, helping to overcome myths that populate common pedagogical sense, such as, for example, the idea that effective science teaching does not require the presence of equipped laboratories, that the AP itself guarantees the learning of students who see the theory studied in practice or that the inefficiency of science teaching in our schools is simply a consequence of the lack of practical teaching, among others. Likewise, discussing practical activities in real contexts, where the training gaps of teachers and students conflict with the lack of "infrastructure", both of schools, teachers, students and their families, as well as the production academic in the area (Bassoli, 2014, p. 591), can enable the construction of teaching knowledge of different natures, aiming to improve articulations and provide deeper discussions on this topic, seeking the critical and effective insertion of AP in different school environments.

This training perspective concerns knowledge and work. For Tardif (2004), teaching practice integrates different types of knowledge, with which the teacher maintains different relationships. "The teacher's knowledge bears the marks of his work, that it is not only used as a means of work, but is produced and shaped in and by work", that is, the teacher's knowledge must be understood in an intimate relationship with work at school and in the classroom, with relationships mediated by daily work capable of mobilizing the creation of strategies to solve everyday situations (Tardif, 2004, p. 17, our translation).

Issues relating to work and its relationships with human beings and their knowledge are highly valued by Tardif, as is the plural and heterogeneous conception of teaching knowledge. In his perspective, knowledge comes from different sources (such as life history; personal culture; the university, programs, guides and teaching manuals and the knowledge of other teachers and his own knowledge linked to peculiar situations of the teaching profession) thus placing the teacher's knowledge between the individual and the social, between the author and the system. From this diversity of sources comes the eclectic and syncretic characteristic of decent knowledge that is mobilized to achieve varied objectives such as motivating, managing students, dealing with situations of indiscipline, evaluating the content worked on, among others (Labarce, 2014).

Tardif (2004) proposes the following typology to organize teaching knowledge:

Professional Training Knowledge: set of knowledge that, based on science and erudition, is transmitted to teachers during the initial and continuing training process. These are pedagogical knowledge related to methodologies, theoretical perspectives on teaching and learning for individuals, didactics, sociology and psychology of education, among other scientifically legitimized content.

Disciplinary Knowledge: knowledge recognized and identified as belonging to different fields of knowledge (language, exact sciences, human and biological sciences, chemistry, physics, etc.). Produced and accumulated by society throughout history, they are managed by the scientific community and access to them must be made possible through educational institutions. Therefore, they imply didactic transposition.

Curricular Knowledge: this is knowledge related to the way in which educational institutions manage socially produced knowledge and which must be transmitted to students (disciplinary knowledge). They are presented concretely, in the form of school programs (objectives, contents, methods) that teachers must know how to learn and apply.

Experiential Knowledge: this is the knowledge that results from the exercise of teachers' professional activity. Produced by teachers through the experience of specific situations related to the school space and the relationships established with students and professional colleagues. They are incorporated into individual and collective experience in the form of habitus and skills, of know-how and knowing how to be (Tardif, 2004, p. 38).

In this sense, the implementation of a practical approach requires teachers to have various knowledge, knowledge and attitudes, which are mobilized simultaneously. When carrying out a relatively simple activity, for example, observing floral structures, the teacher mobilizes knowledge of a conceptual nature (notions about plant morphology and physiology, notions of ecology, etc.); professional training knowledge, as it is important to know how subjects learn, the real role of observation in this process, the importance of raising students' preconceptions about flowers, among others, such as theoretical discussions involving AP; curricular knowledge relating to knowledge of AP proposals with the proposed objective, knowledge of educational products already produced for the same purpose, the level of education at which the activity can be carried out, the safety standards relating to it; experiential knowledge, which will justify certain choices such as, for example, whether the activity will be a demonstration or whether students will use the stylus, whether the activity will be in a group or individual, choices based on previous experiences, known to the group of students, among others that will give the process the "face" of the teacher who will carry it out.

The biology of cognition: some categories for analysis

Biology of cognition or Biology of knowledge are expressions used to designate the epistemology of Humberto Maturana and Francisco Varela. For the aforementioned authors, every cognitive experience, every act of knowing, is based on the biological structure, or even, all knowing depends on the structure of the person who knows. In the search to understand what characterizes living beings, these scholars make an incursion into the cellular universe and arrive at the concept of autopoiesis and the assertion that living beings are defined by their autopoietic organization (Maturana; Varela, 2002).

The concept of autopoietic organization was initially formulated taking the cellular level as its universe. The cell was identified as a first-order autopoietic unit. Cellular dynamics is revealed through a network of interactions that produces the components that "integrate the network of transformations that produce them". Some of these components establish the limits for this network of transformations (morphologically, we can call them membranes), but at the same time they integrate the network. Therefore, the border is a condition for the existence of the network of transformations, and the network is a condition for the production of the components that physically constitute the border and every cellular unit. It is the autopoietic organization that makes autopoiesis possible (Maturana; Varela, 1995, p. 85).

The diversity of life has as its starting point a single-cell stage. This is something common to biological systems, with diversity resulting from variations at a structural level. For this reason, metacellulars are considered "second-order autopoietic systems" (Maturana; Varela, 1995, p. 124, our translation). To understand how the author explains the origin of the aforementioned systems, two theoretical categories are fundamental: ontogeny (history of the structural change of a unit) and structural coupling (concerns interactions with other living beings and the environment). In this sense, the structure of the environment or the structure of the autopoietic unit only triggers changes, it does not cause them. Therefore, there will be structural coupling if the autopoietic unit and the environment do not disintegrate (Maturana; Varela, 1995, p. 113).

Based on the construct that led him to the concept of autopoiesis and studies on the nervous system and perception, Maturana proposed that it is not the environment that determines the experience, as "[...] The nervous system works with internal correlations" (2006, p. 24, our translation). For the aforementioned author, in the same way as living beings, the environment – which constitutes the environment in which beings take place and interact – is endowed with a structural dynamic distinct from that which characterizes living beings. And, in this sense, they state that "[...] the changes that result from the interaction between the living being and its environment are triggered by the disturbing agent, but determined by the structure of the disturbed system" (Maturana; Varela, 1995, p. 131, emphasis added, our translation). Therefore, the environment and living beings are sources of "disturbances and not instructions".

As Maturana and Varela highlight, "the behavior of living beings is not an invention of the system", but what "the nervous system does is expand the domain of possible behaviors, by providing the organism with a tremendously versatile and plastic structure". Furthermore, according to the authors, what we call conduct corresponds to "the description we make of the movements of the organism in the environment we indicate". Therefore, the judgment about a certain conduct is defined by the spectrum of expectations of the observer (1995, p. 167).

From these notes we can present some ideas that are central to Maturana's epistemology and that are important for the present work. For Maturana, it is not possible to explain the phenomenon of knowing without explaining the knower, that is, the human being.

From this perspective, Maturana highlights that "[...] this is our initial condition: we are observers in observing, in the occurrence of daily living in language" (2006, p. 28, our translation). Therefore, we are constantly interacting, acting on each other and immersed in the world of language. Knowing is something inherent to living, it belongs to life and the experience of living in the context of language, which is evident whenever we make a cognitive request, when we question or affirm something to another in the relationship.

Given this, is it opportune to recover what it means to explain? According to Maturana "[...] Explanations are reformulations of an experience, but not every reformulation is an explanation. An explanation is a reformulation of the experience accepted by an observer" (Maturna, 2006, p. 29, our translation). In this sense, science is characterized by a way of explaining and validating scientific explanations and "the operational coherences that they involve" (Maturana, 2006, p. 163, our translation).

The path to validation of explanations, scientific or not, depends on what Maturana called the path of objectivity without parentheses and the path of objectivity in parentheses. On the path of objectivity without relatives (also called dry objectivity by Maturana) “existence is independent of the observer”, making it possible, therefore, to “distinguish between illusion and perception”, as it assumes that it is possible to refer to something independent of the observer. In the second path, that of objectivity in parentheses, “existence depends on the observer”, listening is different, as “reformulations of experience are accepted, with elements of experience” (Maturana, 2006, p. 32-34, our translation). In the explanatory path of objectivity without parentheses “human relations do not occur in mutual acceptance”. In objectivity in parentheses “there is neither absolute truth nor relative truth, but many different truths in many different domains” (Maturana, 1999, p. 48-49, our translation). Therefore, the path of objectivity without parentheses can constitute an epistemological obstacle as it limits the reformulation of some experiences.

The two explanatory paths, or objectivity without parentheses and objectivity in parentheses, that define listening are directly related to emotion. Because, “[...] Emotions are dynamic bodily dispositions that specify the domains of actions in which animals, in general, and we human beings, in particular, operate in an instant” (Maturana, 2006, p. 129, our translation). Therefore, if to understand knowledge it is essential to understand the one who knows (the observer, in observing), that is, to understand conduct in a domain of actions it is essential to consider the emotions that determine them.

Social phenomena imply third-order couplings that, to some extent, are essential for organisms with sexual reproduction. Social phenomena are characterized by structural coupling between individuals, with communication being a particular class of conduct. And, if it is possible to distinguish the instinctive or learned character of behaviors, it is also possible to distinguish the phylogenetic and ontogenetic forms of communication. In this context, imitation, something characteristic of vertebrates, allows an interaction, or even something resulting from the ontogeny of an individual, to be maintained for successive generations. Such configurations, behaviors acquired in the communicative dynamics of the social environment, which remain regular throughout the generations, are called cultural behaviors. (Maturana; VARELA, 1995). It is worth noting that despite the controversy arising from the appropriation of the concept of *autopoiesis*, within the scope of social sciences, in this article, we will restrict Maturana's theorizations, which focus on knowing.

Practical activities carried out with teachers

In this section, a description of the results obtained from two practical activities carried out with teachers will be presented. It is important to highlight that the AP were defined in dialogue with the group of teachers, based on their expressed interests.

Practical Activity 1 : Cellular microscopy of plant tissue

This practice was motivated by PB's interest in the topic "cell biology", a content with which he was working in the 2nd grades of high school. The objective of the activity was to discuss the role of observation in science teaching and in Science itself, and to promote teachers' familiarization with materials present at school that were unknown to teachers. The school had two microscopes and a collection of slides stored in a room used to store books and materials, an unused laboratory. This would encourage teachers to use the materials in their classes. Researchers and teachers PB and PQ participated in the activity.

On this occasion, the following materials were observed under a microscope (there was only one working): i) Sections of stained plant organs, belonging to the researcher's collection (leaf, root); ii) Onion epidermis; iii) *Elodea leaf*, a material that, under medium magnification, allowed a satisfactory visualization of the cell contours and chloroplasts; iv) Human blood smear, mounted on a slide belonging to the school collection.

During the observations, PB and PQ made comments and questions that seemed to indicate that they had several gaps in their basic knowledge on the topic in focus (cell and tissue structure). Therefore, it was necessary for the researchers to indicate to the teachers the structures studied (cells, cell wall, nucleus and chloroplasts), their functions and particularities. Slide staining techniques were also recalled and possibilities for carrying out this practice in the classroom were discussed.

At the time, the researchers chose not to use a script, a decision taken because it was feared that the existence of scripts could distort the meaning of the project - that is, it could signal to teachers that the intention was to provide recipes, or stimulate some teacher simply reproduces the scripts created by the researchers in class. However, in the final phase of the project, when testing the development of some practical activities aided by scripts, the result showed that this strategy was quite useful in terms of putting the discussion of didactic-pedagogical issues at the forefront.

PB was interested in holding a microscopy class with her students, asking one of the researchers to help her develop the class in question. Although she was very interested in using this resource to complement her class, the teacher's lack of familiarity with the microscope and some concepts related to it (images of tissues) was evident. The researcher who accompanied the teacher explained to the students about the use of the microscope, slides and coverslips; assembled and focused the blades; the materials observed were Elodea leaves, onion epidermis and human blood smears; PB explained the observations and tried to control student discipline.

The students were, in general, very interested in the observations and, unusually, one of them showed that he wanted to observe a strand of hair under a microscope. The teacher allowed it, therefore opening up the investigative attitude of the student who was quite surprised to see what the hair structure was like and that it was very close to what was shown in the images in the shampoo commercials. This fact was exciting for the teacher, who was pleased to note the result of her class in “sparking interest in students”.

In a conversation held later, the teacher commented that the first group of students she worked with was a very difficult class and that she was rethinking her idea of working on classes in the laboratory. She said that, as a result of the discussions, she had thought about the idea of completely revitalizing the laboratory and starting all classes there, however, she began to show lack of motivation due to the students' indiscipline. The contradiction between the stimulus generated by the project meetings and the discouragement resulting from the students' indiscipline was clear.

Practical Activity 2: Observation of plant structures in Lily flowers (*Lilium speciosum*)

This activity was carried out following a plant leaf chromatography activity, at the request of PB and PC who agreed that it was an interesting practice to carry out with the students, as “it is much more interesting for the student to see the plant live rather than in images on paper” (PC). Thus, the main objective of the plant structure observation activity was to discuss the possibility of using observations and manipulations of living specimens in science and biology classes and how this type of practice can help students' learning. Researchers and teachers PB and PC participated in the activity.

The specimen observed was a potted lily plant brought by the researchers and which had two open flowers and a bud. PB took the initiative to locate and open a textbook existing in the Library, General Biology (Amabis; Martho, 2009), in which there were explanations and illustrations about the structure and functioning of angiosperm flowers. She began the observations, with a focus of her choice.

First, PB tried to name the parts of the flower, out loud, and asking the researchers for confirmation. Then he asked, to make sure, which were the male and female parts. Therefore, if I were to carry out a practical activity with the students, I would not have enough confidence to even indicate the general location of the male and female structures. He also got a lot of confusion about the names of the different parts of the flower.

Notably, PB had difficulty understanding what the gynoecium (set formed by ovary, style and stigma) was and what the androecium (set of stamens) was. An analogy made by one of the researchers helped her, who played with the fact that the “feminine” element was surrounded by “masculine” elements. PB then commented that, with this “tip”, there was “no way to forget”. Thus, his difficulty was, among others, understanding the relationship between the parts and “the wholes” that could be identified in the flower. It was highlighted, however, that the most important thing was not the names, but having an idea of how the reproduction process took place in plants (angiosperms and others). Thus, although it was the project's intention to stimulate didactic-pedagogical discussions about the practical activity in question, as occurred in other moments of the project, it was necessary to spend a large part of the meeting around the discussion of biological concepts.

Throughout the meeting, several other questions were asked by PC and PB, among which the following stand out: whether the fillets and stylet had an internal channel; whether there were pollen grains inside the anthers; whether it was possible to visualize the eggs by cutting the ovary; what was inside the “flower bud”; what would be the groove observed on the petals; in addition to specific questions about the *Lilium speciosum plant*.

Faced with such questions, the researchers always encouraged, first of all, that the teachers themselves try to “cut” or “open” the parts of the plant in question, to check what they discovered. They also highlighted the importance of a handheld magnifying glass, an instrument that would enable more precise observations about some aspects relating to the issues raised.

At the end of the meeting, it was possible to make a positive assessment regarding the work carried out, highlighting that the participants spent significant time examining the structures of the lily flower, and during this period several questions were raised, hypotheses were formulated and several observations developed in order to test the hypotheses presented.

Analysis and discussion of results

In order to provide an overview of the work carried out and its possible results and limitations, we present below a table indicating the teaching knowledge that was manifested and/or may have been constructed during the reported episodes, accompanied by examples of situations involving this knowledge.

Table 1 – Indication of the teaching knowledge that was manifested and/or may have been constructed during the "Microscopy of plant tissues" activity

Types of Knowledge (TARDIF, 2004)	**Examples of situations in which the knowledge in question was manifested and/or may have been constructed**
Disciplinary knowledge	- During the microscopy activity, PB and PQ made comments and questions indicating that they had several gaps in their basic knowledge about the topics under study (for example, they were unable to identify the cells on the slide under the microscope). External collaborators, in turn, tried to resolve these doubts. - When teaching his class, PB was able to explain to the students the observations that would be made, which indicates that there was improvement in his disciplinary knowledge. - Class planning and the experience of working with students may also have contributed to the consolidation of BP disciplinary knowledge
Professional training knowledge	- When students asked about the structure of a hair, PB encouraged them to carry out observations (putting into practice, therefore, a principle of didactic action, highly valued in current literature, and which highlights the importance of students being stimulated developing investigations)
Curriculum knowledge	- PB came into contact with certain ideas (observing Elodea leaves, observing onion epidermis, etc.) that allowed organizing a practical microscopy class.
Experiential knowledge	- During the meeting with external collaborators, the teachers experienced a process of observation and discussion similar to that which could occur in class. - The teacher used experiential knowledge to plan and establish the structure of her cell observation class. - The teacher "saw with her own eyes" that the practical class developed and the opening given to students to carry out their own observations increased the class's interest in the topic under study (cell).

Source: Prepared by the authors

Table 2 – Indication of the teaching knowledge that was manifested and/or may have been constructed during the activity of "Observation of plant structures in Lily flowers (*Lilium speciosum*)

Types of Knowledge (TARDIF, 2004)	**Examples of situations in which the knowledge in question was manifested and/or may have been constructed**
Disciplinary knowledge	- The difficulty for PB was, among others, understanding the relationship between the parts and "the wholes" that could be identified in the flower (anther, fillet, androecium, etc.). - PC asked questions that demonstrated several conceptual gaps regarding the morphology and biology of plants. - The researchers encouraged observation by the teachers and sought to develop several conceptual discussions. - The teachers consulted the textbook in search of the names and definitions of various structures that make up the flower. - Teachers' statements during and at the end of the work session suggest that they managed to improve their disciplinary knowledge in several areas.
Professional training knowledge	- Reflection on the possibility of working with natural specimens to enrich learning when compared to using images from textbooks.
Curriculum knowledge	- Presentation of a practical activity proposal and new teaching materials for use in class.
Experiential knowledge	- The teachers experienced a practical activity in which they formulated several questions and hypotheses, as well as developing several observations in order to test the hypotheses presented; thus, a process similar to this could be proposed for classroom situations. - The researchers commented that they should have taken magnifying glasses or magnifying glasses, as this would have allowed more detailed images of pollen grains, etc., helping them to take this precaution.

Source: Prepared by the authors

The results presented make clear the importance of disciplinary knowledge for carrying out practical activities. During the activities carried out, important discussions were held, in this sense, so that the teachers' conceptual gaps could be repaired, so that it could be seen that AP can be an important strategy for the construction and reconstruction of disciplinary knowledge in initial training processes and continued.

It is interesting to highlight that, even though she requested monitoring from the researcher, when proposing the microscopy activity to her students PB actively participated in the construction and execution of the plan, as she was the one who established the general structure of the class (form of class organization, class stages, student tasks, records to be prepared). It is believed that to this end, he mobilized his experiential knowledge, that is, he was based on the experience of specific situations related to the school space and the relationships established with these students, based on what he knew about their student classes, the characteristics of them, in the activities he had already carried out with the students and in the activity experienced in the project, in order to plan and adapt the practical activity to the class he was going to carry out.

The teacher's various statements implied the lack of a more detailed analysis of practical activities, which would situate them in terms of their possible functions in the teaching process, the limits of their pedagogical contribution and the need for their articulation with other relevant teaching activities, which therefore refers to gaps in professional training knowledge (Tardif, 2004). On the other hand, in the example under analysis, work experience seems to have provided, among other things, elements of validation of the new way of working (Tardif, 2004). The teacher "saw with her own eyes" that the practical class developed and the openness given to the students, to the observations proposed by them, increased the class's interest in the topic under study (cell).

In fact, it is possible to argue that the teacher learns a lot when an idea for a class stops being a mere idea and is transported to the level of concrete implementation attempts. Work experience generates feedback, contributing to the teacher's knowledge at the end of the process being greater than at the beginning. To delve deeper into the topic worked on by PB, she was provided with an article referring to Bastos' dissertation (1991), which investigated the concept of living cells among high school students.

Thus, although we were not successful in addressing the didactic issues involved with the proposed activity, on the other hand, the discussions raised were rich in terms of the disciplinary knowledge of the participating teachers. Not to mention the experience of situations in which their hypotheses were raised and called into question through observation. It is possible that this experience represented an important gain in terms of the teachers' experiential knowledge regarding the use of practical activities in science teaching.

Next, we intend to make considerations about the experience of carrying out AP with teachers using the biology of cognition as a reference. In order to avoid redundancies, the APs will be treated together.

Initially, it is worth highlighting that the researchers were sources of disturbance for the school and, mainly, for the teachers in the area of natural sciences who agreed to participate in the project, in the same way that they were sources of disturbance for the researchers. The dynamics adopted by the researchers during the interactions, respecting the teachers' knowledge, suggests that the interactions produced couplings with the proposed practical activities, which are also sources of disturbance. This finding suggests that the researchers operated on the path of objectivity in parentheses, exercising listening, giving space for teachers to express their knowledge about the contents of the specific and pedagogical domain involved in practical activities. The fact that the researchers reconsidered the initial request, assumed based on theories in the teaching area, to avoid the scripting of practical activities, also highlights the rationality that was at stake.

The data show that teachers' difficulties, especially with the contents of the specific domain, are directly related to their ontogenies, their experiences in basic education and initial training. In the report, mainly from PB, it is evident that he had to work from an early age to help support his family, therefore, he took part in his basic education at night. In his initial training, his choice was within the spectrum of the possible, since the object of his desire, the dentistry course, was on a very distant horizon. Therefore, he studied his degree in biology at a private higher education institution, also at night, and was aware that many gaps in knowledge resulted from this training. This is corroborated when carrying out the AP, by the questions asked by the teachers, both in the activity in which the microscope was used, and in the activity of observing the structures of the lily flower. It is noteworthy that the emotion triggered by AP, evidenced mainly by PB's behaviors, contributed to content related to experiences being reformulated.

Faced with the proposal to identify the structures of a flower, PB turns to a textbook, which highlights its source for consultation at school and, above all, the presence of this instrument in its ontogeny. For Choppin (2004), the textbook performs four essential functions, which are: referential (curricular or programmatic), instrumental, ideological/cultural and documentary. The production of the book implies a level of didactic transposition, marked by simplifications, mutilations and silencing. This instrument, guided by technical rationality, has played a central role in the organization of didactic work in schools (Alves, 1998). The State of São Paulo (*locus* of the research carried out) introduced bimonthly notebooks, by subject, which represents an even more mutilated version of school knowledge. If official rhetoric places them as a starting point, concrete experience shows that they are also the arrival point. And, it should be noted, these notebooks take on the role of textbooks, including the student's notebook and the teacher's notebook. The fact that the researchers did not make judgments about the material used possibly facilitated conversations and connections with practical activities.

Final remarks

Studies dealing with teacher training have highlighted that one of the greatest difficulties in implementing innovations in teaching is teachers' beliefs about various aspects involving educational practice. In the area of science teaching, this issue is posed as a need to overcome pedagogical common sense, simplistic ideas about science teaching and science.

The experience of analyzing research data based on different theoretical constructs can be a fruitful path for initial and continuing teacher training, however, the imperative to (re)think the designs of training projects is reiterated here. The study revealed that the gaps associated with disciplinary knowledge, with the specific domain, limit continuing education processes, making professional training knowledge marginal. From this perspective, it seems fruitful to bring situations that make it possible to problematize different types of knowledge, integrating them into educational practice, as a way to re-elaborate experiences.

Finally, the involvement of teachers and the knowledge mobilized suggest that a training process, which encompasses specific and pedagogical domains, can be designed based on a menu of practical activities. And, it would be interesting to think about the process from different theoretical matrices. In fact, it would be a way of highlighting one of the variables of educational practice, theoretical references.

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