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Inquiry-based Science Teaching through Constructionism: a path towards scientific literacy

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Abstract: Inspired by the concept of bricolage brought by Seymour Papert to education, this work articulated a theoretical and methodological set composed by Constructionism, Inquiry-based Science Teaching and Augmented Reality, aiming to achieve Scientific Literacy indicators. This articulation was concretized in a biology didactic planning, experienced in the second year of high school in a public school. The search for scientific literacy indicators was carried out by means of Textual Discourse Analysis. The results show that the theoretical-methodological set led the students to construct several indicators proposed in the literature of the area. We conclude that constructionist approaches via inquiry teaching are a viable path to scientific literacy and suggest that bricolage should be a strategy encouraged in basic education teacher training or improvement courses.

Keywords: Bricolage. Constructionism. Inquiry-Based Science Teaching. Scientific Literacy. Teaching Biology.

Enseñanza de las Ciencias por Investigación a través del Construccionismo: un camino hacia la alfabetización científica

Resumen: Inspirado en el concepto de bricolaje aportado por Seymour Papert a la educación, este trabajo articuló un conjunto teórico y metodológico compuesto por el Construccionismo, la Enseñanza de las Ciencias por Investigación y la Realidad Aumentada, con el objetivo de lograr indicadores de Alfabetización Científica. Esta articulación se materializó en una planificación didáctica de la biología, experimentada en el segundo año de una escuela secundaria pública. La búsqueda de indicadores de alfabetización científica se llevó a cabo mediante el Análisis Textual del Discurso. Los resultados muestran que el conjunto teórico-metodológico llevó a los estudiantes a construir varios indicadores propuestos en la literatura del área. Concluimos que los enfoques construccionistas a través de la enseñanza por investigación son un camino viable para la alfabetización científica y sugerimos que el bricolaje sea una estrategia que se fomente en los cursos de formación o perfeccionamiento de los profesores de educación básica.

Palabras clave: Bricolaje. Construccionismo. Enseñanza de las Ciencias por Indagación. Alfabetización Científica. Enseñanza de la Biología.

Ensino de Ciências por Investigação pela via do Construcionismo: um caminho para a alfabetização científica

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Resumo: Inspirado no conceito de bricolagem trazido por Seymour Papert à educação, este trabalho articulou um conjunto teórico-metodológico composto pelo Construcionismo, Ensino de Ciências por Investigação e, realidade aumentada, com o objetivo de alcançar indicadores da alfabetização científica. Essa articulação se concretizou em um planejamento didático de Biologia, experimentado no 2º ano do Ensino Médio de uma escola pública. A busca por indicadores de alfabetização científica se deu por meio da Análise Textual Discursiva. Os resultados mostram que o conjunto teórico-metodológico levou os estudantes a construírem diversos indicadores propostos na literatura da área. Concluímos que abordagens construcionistas via ensino por investigação são um caminho viável para a alfabetização científica e sugerimos que a bricolagem seja uma estratégia encorajada em cursos de formação ou aprimoramento de professores da Educação Básica.

Palavras-chave: Bricolagem. Construcionismo. Ensino de Ciências por Investigação. Alfabetização Científica. Ensino de Biologia.

1 The Construction of the Theoretical Framework: a bricolage exercise

Justifying constructionism, its author Seymour Papert (2008) argues in favor of prioritizing space dedicated to learning over instructionism. Amid this claim, he presents bricolage as a strategy to improve the learning process. Starting from Lévi Strauss's notion of "science of the concrete" about how traditional peoples acquire knowledge, Papert (2008) brings the term bricolage to the field of educational research, giving it the metaphorical sense of "[...] a source of ideas and models that aim to improve the ability to make mental constructions" (PAPERT, 2008, p. 138).

Currently, the concept of bricolage transits through research in education as the possibility of using any theoretical-methodological framework that allows the construction of knowledge about an investigated object and whose choice is more strategic than a merely academic formality; more self-reflective than uncritical (NEIRA; LIPPI, 2012).

To produce a research environment that harmonizes with constructionism in the application of didactic planning in the classroom setting and the design of the investigation, this work allowed to exercise the senses of bricolage described above. As researchers, we faced educational ideas and models to move them in search of a connection that would allow us to build new perceptions about our object of investigation. We also seek to articulate the work with the students by facing them with concrete and abstract resources so that, in their handling, they can build new knowledge in science and about the nature of science.

Among several possibilities, we selected and articulated a specific set of tools for scientific research and educational practice based on the contributions that each one could make to explore the object and the production of knowledge, forming a unique theoretical-methodological framework that, for the freedom of choice of bricolage, considered the sociocultural context of the locus of research, besides reflecting and valuing the researchers' equally unique experiences.

This tool set is composed of: the ideas of constructionism, whose epistemology structures pedagogical action; scientific literacy, which guides the objective of this action; the teaching of science through investigation, which mediates teaching-learning in the abstract plan of action and, finally, the digital information and communication technologies (DICT) that enable students to contact the object of knowledge in a concrete plan. The object of knowledge worked on in this experience aimed at the construction of knowledge about the evolutionary relationships between living beings. The following is a brief characterization of each of the components of this bricolage.

1.1 Constructionism

Constructionism derives from Piagetian constructivism, a theory that sheds light on mental learning operations. According to Piaget's theory, briefly registered here, knowledge is a phenomenon that is not limited to the passive and cumulative transmission of information from one person to another. It is a cognitive process that involves assimilation and accommodation of data in the mental structures of the human being to stimulate a mental organization, aiming to understand the new information, reconstructing it in the interaction with others in the structure of the mind itself. Therefore, there is a cognitive process in which new information meets existing ones, causing imbalances so that it is possible to expand the already structured schemas and/or create more complex ones so that accommodation and, again, equilibrium, can be achieved.

For Papert (2008), the construction of knowledge is more pleasurable when mediated by concrete elaboration, a product that can be shared and discussed with peers. Constructionism discusses the importance of constructions that take place in the world on the mental construction of knowledge so that it becomes a less mentalistic derivation of constructivism (PAPERT, 2008). For the author, the natural context for mathematics learning, for example, would be through participation in other activities and not through the mathematical content itself. Taking this thought for natural sciences teaching, we can say that the natural context for learning is the elements of concrete life in society and not the scientific content itself.

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By encouraging the educator to extract parts of the social context that deal with a specific scientific issue, we allow the students to construct knowledge with more complex relationships and meanings, since both its scientific and social dimensions are at the base of the problematization of that issue. In this way, students can expand their cognitive structures about scientific knowledge, providing, at the same time, the construction of practical social meanings about knowledge.

The term *computational thinking*, which refers to computer science skills in problem solving, was created within constructionism (PAPERT, 1980). Papert (2008) defended the use of the computer in didactic activities as a tool capable of constructing actual products in the concrete world simultaneously with the mental construction of new ideas. Although commonly associated with mathematics learning, computational thinking is currently seen as a cognitive process that uses the fundamentals of computing in several areas of knowledge, both for identifying and solving problems (WING, 2017).

1.2 Scientific literacy

Therefore, the constructionist perspective registered before aligns with the scientific enculturation (*letramento* in portuguese, here will be translated as enculturation), which, in a broad sense, refers to the acquisition of conceptual and methodological knowledge in the areas of science, along with mastering their language and capacity of expression within the scientific culture, in addition to the competence to use such knowledge to reflect and act critically about the products of science and their impacts on society, either as a basis for individual choices or in public debates involving the common good (MOTA-ROTH, 2011).

However, even if scientific enculturation encompasses more than the aspects involved in the formal teaching of science, as defended by Cunha (2017), for it to occur, the subject must access to the basic tools of science, comprising scientific concepts about natural phenomena and scientific theories and the very nature of science, its history, and its methodologies. In other words, scientific enculturation requires scientific literacy.

Enculturation and literacy are distinct but related concepts. In language studies, enculturation corresponds to the sociocultural uses of written language, and literacy corresponds to understanding the linguistic code and acquiring skills related to reading

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and writing (SOARES, 2018). In that area, enculturation and literacy are expected to be built together in the education of the subject (SOARES, 2017) so that the use of these terms in science teaching brings with it the same senses and gives rise to the same joint action, i.e., scientific literacy as the acquisition of scientific language — conceptual, procedural and epistemological —, and scientific enculturation as the competence to make sociocultural use of that language.

Another critical point is that scientific literacy emerged in discussions about science teaching as an objective that must be achieved in education. It is a state the subject can reach through formal education. Concerns about scientific literacy date back to the mid-twentieth century in the United States to respond to the political context of post-World War II and the beginning of the Cold War. These events boosted a race for technoscientific advances under the excuse of national security (DEBOE, 2000). In this scenario, governments were concerned about the training of new scientists and public support for heavy investments in the area, but the civil institutions also worried about the problems that such technoscientific advances could bring to humanity (DEBOE, 2000). After all, the memory of war and its weapons of mass destruction were still very recent.

From the 1970s onwards, there was an increase in environmental movements that denounced the problems arising from excessive consumption and scientific-technological production on the climate, ecosystems, biodiversity, and even human health. Therefore, in the 1980s, with the end of the Cold War, space was opened for new reflections on science education.

The relationship between science and society, along with technological applications, was again promoted as a goal of the science curriculum. However, the term *scientific literacy* was used to describe a broader study of science, especially in relation to its everyday applications (DEBOE, 2000). In the new political-social context, it begins to adopt the notion of training in sciences also for social action, aiming at the constitution of critical awareness about the products of science and technology, as well as the construction of competencies for more active political participation (DEBOE, 2000). It is clear, then, that the strengthening of discussions in favor of science teaching also focused on scientific enculturation.

Since then, research in the area has explored the means that the school can use to achieve these goals, and constructivism, together with approaches in science teaching by investigation, has been highly requested in those explorations (CAMPOS; KAHLIL, 2019). Similarly, research in the area is dedicated to finding out indicators that students have already achieved or are in the process of achieving in both scientific literacy and scientific enculturation (PIZARRO; JÚNIOR, 2015; SASSERON; CARVALHO, 2008).

According to that view, this work presents and evaluates a planning of biology teaching, epistemologically anchored in constructionism and having the Inquiry-based Science Teaching as a educational approach, focusing on scientific literacy. The curricular content worked on in this experience aimed at the construction of knowledge about the evolutionary relationships between living beings. Although the main goal was to make the students scientifically literate, we want to clarify that other teaching units are needed to build aspects of scientific enculturation on this topic in addition to the lessons given.

1.3 Inquiry-based Science Teaching

The inquiry-based science teaching (IBST) consists of a educational approach that enables science learning either through the acquisition of factual or procedural knowledge or through the development of skills that enhance learning through practice (CAMPOS; KAHLIL, 2019). The practice consists of modeling some stages of the scientific method, transposed to the school context, of which the formulation of hypotheses and arguments and the problem solving through inquiry stand out (CAMPOS; KAHLIL, 2019). This can have different difficulty levels depending on the approach implemented (BANCHI; BELL, 2008).

The conceptualization of the IBST as a teaching approach is also defended by Sasseron (2018), for which the type of strategy the teacher uses is less relevant than the presence of scientific and epistemic practices in the chosen strategy and tasks. However, the mere fact of these elements is also not enough to define a strategy like IBST. From the results of research on science teaching and referring to John Dewey and Paulo Freire, the author presents five elements that merge to form the idea of IBST, namely: the students’ intellectual and active role; learning beyond conceptual content; education by presenting new cultures to students; building relationships between everyday practices and teaching practices; and learning for social change.

Thus, there is no specific step by step for the IBST, but a conception composed

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of elements indicative of paths that can be built in different ways, but that lead to the same end, so that the differences between the methodological strategies based on the IBST result in different denominations: project-based learning; discovery teaching; problem-based learning; open questions; open problems; experimental demonstrations, and open laboratories. In this sense, Campos and Kahlil (2019) call it polysemic and emphasize that the role of the teacher in the IBST is malleable, since the approaches and epistemological bases on which the IBST can be anchored are variable. Nevertheless, in a critical analysis of the literature, the authors noted that in most Brazilian experiences, approaches are structured in advance, which gives the teacher a central role.

In the present work, the use of IBST in the light of constructionism is justified in the appeal it makes to the student's active action for the concrete handling of elements in the construction of specific knowledge. Derived from constructivism, constructionism places more emphasis on modes of learning and their relationships with the social, emotional, and structural context in which they take place (SANTOS *et. al*., 2021). The author defends manual constructions and their sharing as ways of mental concrete operations that help or build new knowledge. Thus, in the context of an IBST approach, we believe that constructionism can enrich the link between the sociocultural aspects of learning, content, and scientific practice and provide more space for students' autonomous action in the inquiries proposed by the IBST.

1.4 Augmented reality

Constructionism pioneered the use of digital communication and information technologies (DICT) for educational purposes, inspiring the development of software for education in a period in which the computers were far from social use, compared to the present day (SANTOS *et. al*., 2021).

For Papert (2008), learning occurs spontaneously and effectively when elements not yet assimilated into a concept are used concretely, i.e., in a useful action to construct a specific product, be it a cake or a painting on the computer screen. Those scenarios naturally allow the interaction of the familiar with the new, which is essential for learning because, from this interaction, a chain of ideas leads to the construction of the very knowledge.

However, regarding the use of the computer, the author warns that the external

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environment also needs to be rich in possibilities of concrete interaction with the object of knowledge because "[...] nothing could be more absurd than an experience in which the computers are placed in a classroom where nothing else is changed" (PAPERT, 2008, p. 143). To try to avoid such absurdity, in this work, the DICT was inserted in the sequence of classes as an element incorporated into the IBST approach, as a strategic resource within the methodology. Strategic, because its function is to: a) be a differential element that arouses curiosity and, therefore, motivates the student; b) constitute a digital technological element as a mediator of the manual construction process and, also, cognitive in the molds of what constructionism defends and; c) transform elements of daily use into resources for learning, thus expanding the space for action and pedagogical interaction in class.

Thus, the first instrument present in classroom to be used in a resignified way in this teaching planning were students' cell phones, which, from being objects of distraction, became resources for stimulating and mediating learning. Even though young people today are digital natives, with great ease of use of technologies, they are not prepared for the challenges technologies pose, as their use is usually oriented towards consumption (FIGUEIREDO, 2019). Nonetheless, the popularization of these devices brought the opportunity to create tools, such as app and software, for different literacies, including digital literacy and scientific literacy. Mobile education, mobile learning or m-learning is the concept that emerged to support the idea that education can be mediated by mobile tools and devices, such as tablets, smartphones, iPods, among others (MÜLBERT; PEREIRA, 2011).

In this context, we insert the free AR3D augmented reality app in this research. It was created within the scope of the master's program in biology teaching at the Universidade Federal do Pará, Brazil (SILVA, 2019). It was structured for mobile devices with an Android operational system and presented a new way of observing species of the arthropod phylum by combining virtual 3D elements of the species with the real environment. The application installation comes with a PDF file with bookmarks for 60 species. When printing the markers, point the cell phone camera at one of them, and the image of the species appears in augmented reality, allowing the user to interact with it on the device screen (SILVA, 2019).

Augmented reality app on mobile devices are viable technological approaches to involve students in the basic education process since it makes it possible to explore

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their virtual resources integrated with real-world elements from an educational perspective (HERPIC *et al*., 2017). The use of augmented reality mixes the virtual and the real so that the entire concrete environment where it is employed can enter the virtual scenario, causing real interactions with the object of study. This interaction expands the range of knowledge and skills accessed by the student, contributing to the construction of new knowledge from a constructionist perspective. Depending on the references and creativity of teachers and students, the use of augmented reality makes it possible for all spaces and objects to acquire pedagogical potential.

2 Methodology

The articulation of the theoretical-methodological set previously described was carried out around the biological classification of the arthropods group in a 2nd-grade public high school class in Belém city, Pará, Brazil. Twenty-six students participated in the class, and the main objective was to mobilize the knowledge they already had about the general characteristics of the phylum Arthropoda and, also, about biological evolution to investigate the possible evolutionary arrangements of the groups of this phylum commonly mentioned in the textbooks of biology: crustaceans; insects; myriapods, and chelicerates.

To achieve this goal, two IBST approaches were used in sequence: a) open question and b) open problem, both as in Carvalho (2014), according to whom the open questions require the use of prior information or the gathering of new information to be solved, while open problems require that information be gathered and mathematized to reach a solution. The approaches used can also be classified as “structured inquiry”, difficulty level 2, in which students investigate an issue through the procedures proposed by the teacher (BANCHI; BELL, 2008).

It is noteworthy that before applying this teaching planning, the class teacher held review classes on the two themes that the students would mobilize and sensitized the group to download the AR3D app, which would be used during the investigation of the open problem.

For the open question, the students relied on their memories of the species to build their initial hypotheses about their possible kinship. However, to solve the open problem, they were oriented to gather more information about the body structure of the species using the AR3D app and organize this information in a numerical matrix to compare the morphology between the different groups identified. Thus, based on the results, they should propose a second hypothesis that better reflects the possible evolutionary kinship among the groups to confirm or refute the hypothesis constructed at the beginning of the class. Finally, four cladograms were presented to the students to choose the one that best translated their final hypothesis.

Chart 1 presents the teaching planning that we developed for this work in detail.

Table 1: Detailing of the teaching planning

LESSON PLAN			
About the class			
Time	Three-hour class*		
Topic	Biological classification of arthropods phylum.		
Objective	Recognize the characteristics of the arthropod classes and explore the evolutionary kinship among them based on the analysis of the presence/absence of specific characteristics.		
Competence (BNCC)	**General**: Use different languages and digital information and communication technologies to communicate, access, and disseminate information, produce knowledge and solve problems of the natural sciences in a critical, meaningful, reflective, and ethical way. **Specific**: Analyze and use interpretations on the dynamics of life, Earth and the Cosmos to develop arguments, make predictions about the functioning and evolution of living beings and the universe, support and defend ethical and responsible decisions.		
Skill (BNCC)	To analyze the different forms of manifestation of life in its different levels of organization, and the favorable environmental conditions and the limiting factors to them, with or without the use of digital devices and applications (such as *software* simulation and virtual reality, among others).		
Strategies			
1st class: Contextualization and proposition of the open question	**2nd class: Proposition of the open problem**	**3rd class: Systematization**	**Constructionist and/or investigative aspects**
Dialogue encouraged by the teacher about arthropods commonly found at home or in the squares and parks of Belém. The teacher lists the arthropods mentioned by the class on the board. **Open question**: Among the animals mentioned, are there evolutionary kinship relationships?	**Open problem**: (1) Use the AR3D app to observe the morphology of the arthropods present in the markers you received. (2) Divide them according to taxonomic groups: crustaceans; insects; myriapods, and; chelicerates. (3) Give each characteristic a value and fill in the "taxonomic groups	Write a paragraph about your results and construct a cladogram that shows the possible evolutionary relationships between the resulting arthropod groups from your matrix.	1 Proposition of open tasks enabling the construction of different hypotheses. 2 Guidance for building the best possible answer rather than looking for the correct answer; 3 Possibility of concrete interaction with the subject of study within the

Justify your answer.	versus characteristics" matrix with those values. (4) Interpret the evolutionary relationships of taxonomic groups from the matrix results.		school environment. 4 The DICT as a tool for motivating and mediating learning, through simulations, generating stimulus for autonomous reasoning and construction of hypotheses. 5 Opportunity to elaborate arguments based on science, given the results.

* Hour/class: Corresponds to the productive duration of the class, defined by each school institution. In the school where this plan was implemented, one-hour class corresponds to 45 minutes.
Source: Authors

2.1. Data collection and analysis

The research adopted a qualitative approach and, for that, it used participant observation, which takes place through the direct contact of the observer with the social actors within their cultural context, in which the inquiry instrument is the researcher himself (CORREA, 2009), and the analysis of texts produced by students in class. Textual analysis in qualitative research is not aimed at testing hypotheses but at understanding the phenomenon investigated through a careful and rigorous analysis of the textual body (MORAES, 2003).

Thus, we opted for the discursive textual analysis to assess whether the teaching planning, produced with the theoretical-methodological package previously exposed, led to the construction of students' scientific literacy (MORAES, 2003). The above because we consider that, for the focus of our research, the survey of textual categories related to the conceptual, procedural, and epistemological knowledge of the sciences, analyzed within their discursive context, is sufficient to point out whether indicators of scientific literacy emerged in the path followed. Such indicators are based on Sasseron and Carvalho (2008) and Pizarro and Júnior (2015), according to Chart 2.

Chart 2: Scientific alphabetization indicators in Sasseron and Carvalho (2008) and Pizarro and Júnior (2015)

Indicators in Sasseron and Carvalho (2008)
Work with the data: information seriation, organization, and classification.
Structuring of the thinkin: logical and proportional reasoning.

Understanding the analyzed situation: raising and testing hypotheses, justification, prediction, explanation.
Complementary indicators in Pizarro and Júnior (2015)
Articulate ideas, investigate, argue, read in science, write in science, problematize, create, and act.

Source: Authors

The corpus of analysis included: a) *the* speeches produced in the first part of the class during the open question; b) the speeches produced in the second part of the class during the argument in defense of the hypothesis produced in the open problem; and c) the cladograms selected by the students in the third part of the teaching planning. Thus, of the twenty-six students who participated in the class, we selected the productions of eight (30.7%) to compose our sample. The selection criteria for this sample were: a) full participation in class since some of the students arrived late; and b) the saturation criterion, when the analyzed texts had very similar meanings and no longer produced new information and, thus, changes in the results already achieved, as Moraes (2003) says.

3 Results and discussion

The discursive textual analysis (DTA) of students' productions on the open question resulted in three categories and five subcategories, according to the diagram in Figure 1.

The names mentioned in Figure 1 are fictitious and substitute the students' real names. Each category corresponds to the different hypotheses the students formulated in class about the evolutionary relationships between groups of the phylum Arthropoda. To reflect on the open question, they mobilized the knowledge acquired in previous lessons on biological classification and evolution and their memories and personal knowledge about this phylum, given that several of its representatives are commonly found in an urban environment.

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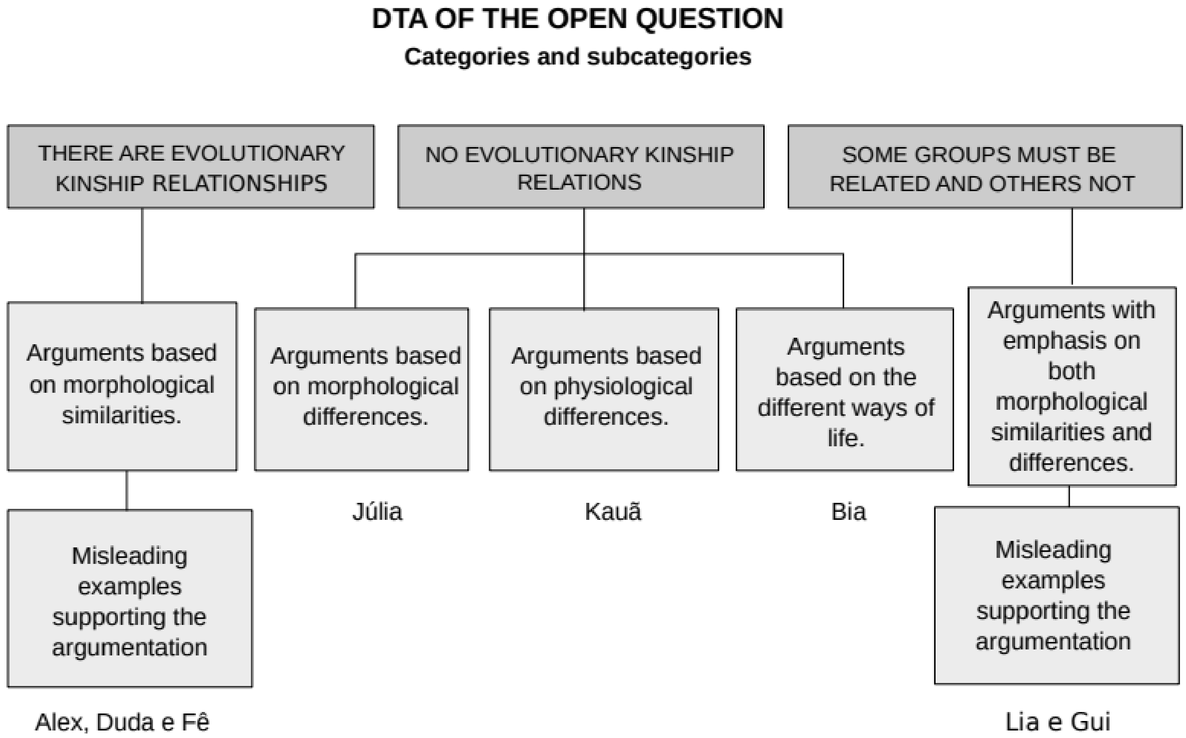
Figure 1: Categories constructed from the discursive textual analysis of the students' written answers to the open question



Source: Research Data

In this scenario, three hypotheses emerged: a) all arthropods have evolutionary kinship relationships; b) arthropods do not have evolutionary kinship relationships; and c) some groups of arthropods present evolutionary relationships unlike other groups, and are grouped arbitrarily. The arguments to support the hypotheses were as follows: for the first hypothesis the morphological similarities were more important; for the second hypothesis the morphological and physiological differences and differences in ways of life were more important; and for the third hypothesis both arguments were used. However, in cases where students looked for examples to reinforce their arguments, they contained numerous errors, as in the following excerpts:

> Alex: […] the presence of antennas, **wings**, and several pairs of legs in different arthropods, such as centipedes and cockroaches, attest to what I have just said (hypothesis 1).
>
> Gui: […] for example, cockroaches and beetles must be closely related, since they both have exoskeletons and six **or more** paws.

At the open question, the students were not yet using the AR3D augmented reality application or any other support such as the textbook; for example, so they only appealed to their own memory to recall the morphology of arthropods and reflect about their possible evolutionary relationships. Thus, it is understandable that

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misconceptions, such as the presence of wings in centipedes and a higher number of locomotor appendages in insects, have arisen, and the reference to a general characteristic of the entire phylum, such as the presence of an exoskeleton, which is emphasized as a distinctive feature of insects. However, most important was the mental exercise of comparative morphology they performed seeking to support their hypotheses.

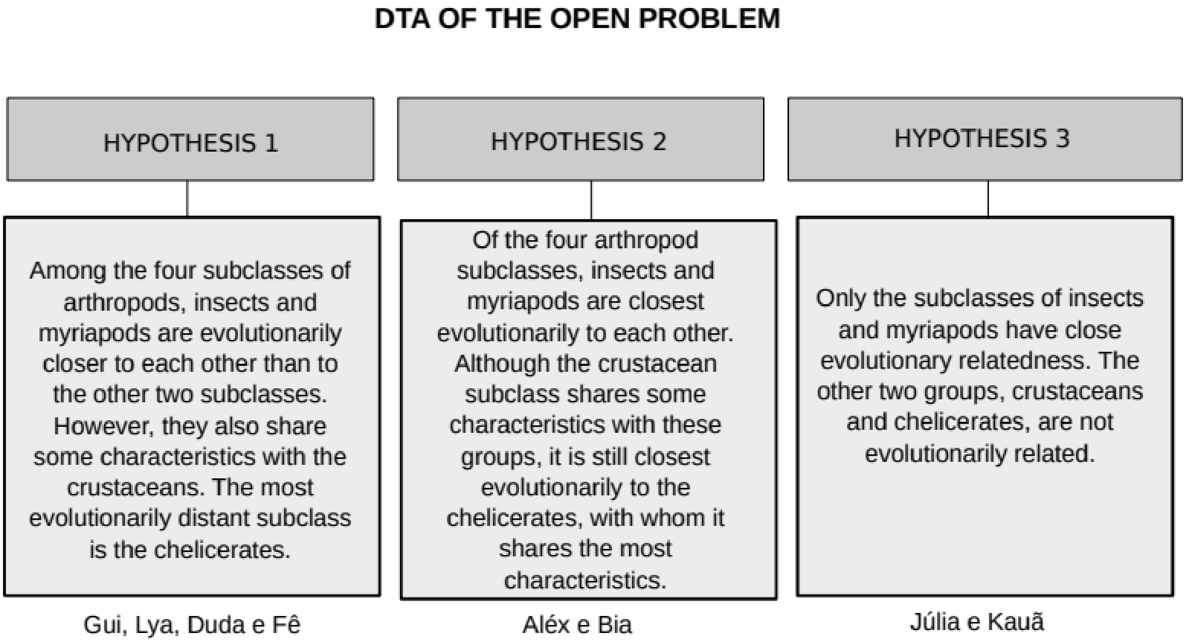
It draws attention that, even having received previous classes, some students still denied possible kinship relationships among the groups, focusing their attention on what differs them and ignoring what brings them close. This action may indicate students' poor understanding of the concepts and processes presented before or that they are simply denying the theories presented.

The purpose of the open question was precisely to lead the students to formulate the hypotheses, as they themselves would confront them when solving the open problem, which was structured in a way that they would observe more carefully the morphological characteristics that divide the groups of arthropods so as, then, in the opposite direction, to associate them to infer the order of appearance of those characteristics in the groups and their evolutionary relationships.

Thus, in the same way, as in the open question, the DTA of the students' productions about the open problem resulted in three categories corresponding to three hypotheses (Figure 2). However, they presented significant changes in relation to those hypotheses that emerged in the open question.

First, the hypothesis that arthropods do not have evolutionary relationships has disappeared. Secondly, the hypotheses created at that time already sought explanations about how the arthropod groups would be related in the evolutionary history of the phylum, relying exclusively on the morphology of the groups. It is worth noting that, during the class, the professor emphasized that other scientific methods were used in the systematics, such as physiology, embryology, and comparative biochemistry. However, he explained that comparative morphology plays an important role in the history of science. It is one of the first techniques to base biological classification on evolution, forming taxonomic groups that were later confirmed or refuted by the techniques that followed.

Figure 2: Categories constructed from the discursive textual analysis of the answers to the open problem



Source: Research Data

The three hypotheses created in the open problem agree that the group of insects is closer to the group of myriapods; however, they differ in terms of the position of crustaceans and chelicerates. In the first hypothesis, crustaceans would be closer to insects and myriapods. In the second hypothesis, they would be closer to the chelicerates and in the third hypothesis, the students did not find enough evidence to give an opinion.

Between the two activities, we observed that students changed their positions significantly. For example, Júlia, Kauã, and Bia initially said there were no evolutionary kinship relationships between the arthropod groups. In the open question, Bia said:

> Bia: […] some live in water and others are terrestrial and despite being all arthropods, there are several characteristics so unique and different that they suggest that they have different origins.

Nevertheless, after the virtual interaction with the species via the AR3D app and after the mathematization of the general characteristics of each group by filling in the matrix, the student could visualize indications that the groups could be related so that she formulated the following analysis while solving the open problem:

> Bia: […] in the division of the body, insects are closer to myriapods and chelicerates are closer to crustaceans. The presence of antennae brings insects, myriapods, and crustaceans together and keeps them away from the chelicerates. With locomotor appendages, insects are closer to myriapods and

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chelicerates than crustaceans. The buccal appendages bring insects, myriapods, and crustaceans closer and away from the chelicerates.

In the same way, Júlia and Kauã also revised their conceptions on the subject, however, they were only able to visualize the relationships between insects and myriapods, thus building hypothesis 3. Lia and Gui, in turn, who initially considered that only part of the groups had relationships, also showed significant changes when constructing hypothesis 1, assuming that all groups are related.

Depending on the investigation, the first hypotheses were revised to be later abandoned or reconstructed based on new reflections on the subject. It is important to highlight that the students built both the first and second hypotheses autonomously. The teaching planning anchored in constructionism actually provided more space for learning to the detriment of instructionism, as defended by Papert (2008).

In this scenario, the class teacher was the strategist, coordinating the class performance without interfering with the answers that the students built individually, which provided a richer environment in autonomous learning. The coordination enabled the moments established in the planning to be executed and the mediating resources mobilized (previously presented didactic content, the AR3D app, the construction of the matrix, the investigative stance, among others) in leading the class to the objective outlined for the lesson, in this case, scientific literacy.

Thus, based on their previous knowledge and available resources, the students were free to make the most diverse mental associations to solve the question and the problem presented. In this way, they themselves criticized when raising evidence against or in favor of the hypotheses they built at the beginning of the class. Although not explained by the professor, the moments of data collection and organization, analysis of results, review, and criticism of initial ideas were necessary for the contact and exercise of principles of scientific methodology, which constitutes an indicator of the construction of scientific literacy. Our approach led to the appearance of the three groups of indicators proposed by Sasseron and Carvalho (2008) in the students' actions.

During the open question, the emphasis was on mobilizing previous knowledge – systematics and evolution. The challenge embedded in the question demanded that this knowledge be associated separately to build a logical solution. As the teacher did not censor their answers, i.e., there was no right or wrong answer, the students were

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autonomous enough to build their hypotheses and expose their logic.

Thus, in the open question and in the open problem, the students made autonomous associations between the concepts and processes related to biological classification, comparative morphology, and evolution. Such associations were required to solve the challenges that the activities brought and their accomplishment configures the constitution of a new learning, which allowed the construction of hypotheses about the evolutionary kinship among the groups of arthropods and that resulted mainly in a more concrete notion of the term *evolutionary kinship,* which had been abstract until then. This idea of evolutionary kinship was materialized in the construction of the second hypothesis and reflected in the choice of the cladogram that best represented it.

Therefore, we perceived that the formerly static and distant knowledge gained movement, was deepened, became more interesting, and acquired meaning for the student, who had protagonism and intellectual autonomy. This aligns with the spontaneous and effective learning advocated by Papert (2008), who argues that the constructionist approach has the potential to move elements not yet assimilated into a concept toward the construction of a specific product, which provides the interaction and chaining of old and new ideas, leading to the knowledge construction.

In the inquiry of the open problem, the use of the AR3D app enriched the classroom environment by allowing the visualization of the species in augmented reality and movement, becoming a new possibility of interaction with the subjects of study. In this way, it worked as a source of data for the students in exploring the morphology of arthropods, but also as an element of motivation for a positive attitude towards the class, with more interest and willingness to carry out the proposed activities.

The use of AR3D, together with the task of filling in the matrix, building hypotheses, and choosing the cladogram, allowed the four pillars of computational thinking to be addressed (VICARI; MOREIRA; MENEZES, 2018): the problem was decomposed when each of the groups were analyzed separately; then, when the characteristics were transformed into numbers, there was a search for patterns shared by the different groups; so, the differences exposed in the matrix had to be considered irrelevant so that the possible kinship relationships could be abstracted in the matrix analysis and, finally, there was the construction of a general notion about biological classification anchored in evolutionary history, particularly, a notion of the steps to follow in the search for evolutionary kinship between species or groups of species.

With this, we observed that the IBST approach implemented via constructionism and mediated by the AR3D app enabled the exercise of computational thinking, becoming a practical example to corroborate the idea that skills related to computer science can be useful for teaching- learning other areas of knowledge (WING, 2017), mainly mathematics, the basic education subject matter most commonly related to computational thinking, which is the only module encouraged by the *Base Nacional Comum Curricular* (BNCC - Nacional Common Curriculum Base) (BRAZIL, 2018).

The results show that the theoretical-methodological set of didactic planning implemented generated indicators of scientific literacy. From those indicators pointed out by Sasseron and Carvalho (2008), in this class, the students performed the seriation, organization, and classification of information while observing the species via AR3D, together with consultating previously established information; they exercised logical thinking when they had to abstract evidence of evolutionary relationships from the matrix; and raised, tested, corrected, and justified their hypotheses with arguments based on the data they collected. Those actions mix the consolidation and deepening of scientific concepts and processes with the knowledge of the scientific methodology itself, which is essential for the beginning of the scientific literacy process (SASSERON; CARVALHO, 2008).

From the indicators proposed by Pizarro and Júnior (2015), this approach managed to: articulate ideas, mainly among previous knowledge, but not yet related to biological classification, morphology, and evolution; investigative stance in the search for answers anchored in evidence in the face of the proposed problems; argumentation, which occurred initially confused in the open question, gaining consistency in the open problem; creation, explicit in the construction of hypotheses; writing in science, when mental articulations had to be organized in written language; and reading in science, which showed itself in the interpretation of cladograms that best represented their hypotheses.

4 Conclusions

The choice of the theoretical-methodological framework used in this research resulted in the construction of scientific literacy indicators proposed by Sasseron and

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Carvalho (2008) and Pizarro and Júnior (2015). Students constructed the indicators during class, i.e., they were not a mere extraction from the teaching planning. This means that the approach used efficiently led to the production of indicators in the classroom instead of their mere exhibition as if they appeared regardless of the strategies chosen by the teachers.

The bricolage exercise that we proposed allowed us to explore different pedagogical resources, positioned in different places, and with different functions within a didactic plan whose focus was on scientific literacy. By having different origins and being in various positions, each piece of this bricolage provided us with a different view of the process.

With the constructionist approach, we observed the importance of converting the environment and available resources into concrete objects of exploration, inquiry, and data source to promote the clash of previous knowledge with new objects of knowledge. The notion of building a product as a means of learning gave concreteness to the students' hypotheses. Their hypotheses constituted that product, built and reconstructed during the process, then shared and defended by students in arguments consistent with the objects of knowledge we intended to work on in class.

We also observed that the IBST added elements of scientific practice to planning and established a bridge between constructionism and scientific literacy. Moreover, the AR3D app was a motivational element for the students, and a data source for the IBST approach and computational thinking.

However, although the theoretical-methodological framework used can lead to the construction of indicators of scientific literacy in the classroom, the teacher must be aware of the purpose of the class itself about the reasons for choosing the strategies used. He/she also must be fully engaged in students' guidance and motivation so that they achieve the expected result. Therefore, this work does not intend for this pedagogical planning to be a recipe to be followed unchanged in search of the same results. Rather, we want the bricolage that inspired this planning also motivates Basic Education teachers committed to teaching Science and Biology to expand their knowledge about the diversity of theories, techniques, and pedagogical resources.

Expanding knowledge can favor teachers' autonomous assembly of different theoretical-methodological frameworks in connection with the objectives they establish for their classes. Thus, we suggest that bricolage exercises can be a strategy

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encouraged in the initial and continuing teacher education, as they have the potential to contribute to the expansion of their knowledge and autonomy. Otherwise, how can we demand that teachers lead students to be protagonists and exercise autonomy, something highly defended by various studies and incorporated into the BNCC if, at the same time, we give those educators ready-made recipes? Teachers must also be protagonists and autonomous in their profession to demand such stances from their students.

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