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Education

# Ecotoxicology At School: A Proposal For Insertion Into Practical Science Classes

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**Abstract**

The complexity of environmental effects, caused by the diversity of chemical compounds interacting with the biota, brings to light the urgency of an emancipating education focused on integral human formation. In this sense, there is a concern about appropriately working with themes relevant to environmental education for students in the early years of primary education. Thus, educators in the field of biological sciences are allowed to approach topics related to biodiversity, to educate for citizenship, in the perspective that students recognize themselves as part of the environment. Problem-Based Learning - PBL involves questioning based on the observation of phenomena, hypothesis testing, and analysis of results, being an ally of science, considering that the student is the protagonist in the different stages of knowledge construction. Based on this methodology, auxiliary materials were prepared for use in the classroom, guided by concepts and playfulness. To contextualize the phenomena involved in the study of ecotoxicology, a survey was carried out of the contents and abilities of the Brazilian National Common Core Curriculum (BNCC, as per the acronym in Portuguese), listing the potentials to be examined together with the concepts of ecotoxicology. For these, bioassay protocols were chosen for the elaboration of practical activities that exemplify the thought phenomenon. Two skills were selected for the elaboration of stories that describe problematization, the accomplishment of the experimental activity, and the presentation of the results of the experiments throughout the character's daily life. The area's theoretical and practical framework involves using technical terms, which can compromise students' interest and learning. To remedy the difficulty with the concepts, a mini dictionary was created with definitions and optimization of technical terms to simplify the research process and the student's understanding.

Keywords: Citizenship Training, Environment Contaminants, Education, Scientific Method, Storytelling.

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## INTRODUCTION

Ecotoxicology is a science that was created linked to ecology and toxicology and currently represents a significant effort to demonstrate the effects of different chemical compounds on organisms. Regarding formal education, ecology is included in the science curriculum component, bearing in mind the contents of environmental education which, according to the Brazilian National Common Core Curriculum (BNCC), are distributed throughout all grades of the elementary school in thematic units matter and energy, life and evolution, and earth and universe (BRASIL, 2018).

The highlight of ecology in science is presented by the possibility of student involvement with the problems of pollution impacts on the environment and the way they bring consequences to human populations. Through the approaches in these classes, elementary school students have access to information about biodiversity and the contribution of different species in maintaining ecosystems. In addition, concepts involving the conservation and preservation of areas make it possible to expand the student's repertoire in relation to how human beings need to see themselves as integrated into nature.

The possibility of teaching ecotoxicology added to the formal science content in elementary school can be challenging for teachers, but it is also an important way to contribute to the integral formation of the individual. Considering this possibility, one of the ways to contextualize this scientific content to the others taught at school is the use of methodologies that can help students understand science and the scientific method through the observation of experiments and phenomena, formulating the problem and raising the hypotheses, collecting and analyzing data, and obtaining conclusions about the studied phenomenon (CASTRO *et al.* 2018; SANTOS FILHO. R. *et al.*2020).

It is notable that, in the classroom, students' interest is aroused from the moment they are introduced to an activity that situates them as protagonists in the production of knowledge. Thus, Problem-Based Learning - PBL has the potential to increase learning capacity due to the involvement of students with the subject of the class (GUIMARÃES, 2009) favoring learning for citizen training, influencing the way how they learn, re-signifying the initial knowledge, making them protagonists in the discussion of the observations of the phenomena, in the problematization, in the hypothesis test, and in the obtained data analysis.

It is understood that the concepts involving ecotoxicology are complex since toxicology and ecology approaches are necessary. However, regarding the results that this science brings about the lethal and sub-lethal effects on living beings, and the discussions that are underway aimed at improving Public Health (DOS SANTOS, *et al.* 2020. ROUSTAN, *et al.* 2014), it is clear that environmental education efforts need to be converged to teach, still in the initial series, the importance of paying attention to the available concentration of contaminants in the environment, enabling, among several discussions, the Sustainable Development Goals (SDGs) 2, 4 and 12 (BRASIL, 2019).

To be able to work on theoretical and applied concepts, it is necessary to have an adequate didactic transposition of the formal content, which is why how contextualization is carried out is essential. Thus, there must be theoretical and practical subsidies so that the teacher in the classroom can address current issues involving pollution and environmental impacts with students during science classes.

Considering the current environmental situation and the scope of science classes in elementary education in Brazil, as well as the importance of working with students on science in an applied way, from a comprehensive and citizenship perspective of education, the guiding hypothesis of this work, was that it is possible to develop classes based on PBL, using concepts of ecotoxicology, which are consistent with the formal content proposed for the Brazilian education. Thus, the general objective of the work was to carry out a survey on the contents and abilities of the BNCC, to accomplish the proposition of an approach to concepts of ecotoxicology in classes, and to develop an auxiliary material to be used in the classroom that elucidates the approached phenomena, contributing with the scientific literacy in the basic education levels.

## MATERIALS AND METHODS

The research was carried out in two stages: 1) the Review Stage and 2) the Activity Proposition Stage. In the first stage, based on the bibliographical research methodology of the narrative review type, a content organization strategy was outlined to address the topic of ecotoxicology at school using the BNCC as a database.

It was selected one BNCC skill per year of the elementary school was selected in which ecotoxicology concepts can be inserted throughout the study of contents.

Based on the selected contents, the concepts of biology that could jeopardize the students' understanding were analyzed, due to the complexity involving technical terms. Based on this, a mini dictionary was developed to serve as support material for teachers and students. It can be used during research and discussion of the analyzed data.

With this first delimitation of the stages of this research, the Review Stage starts with reading the skills described in the BNCC database and the search for one skill per school year that contained contents that deal with the preservation of the environment was made.

After this process of choosing the skill, still in the Review Stage, an analysis of the biological concepts involved in these contents was carried out, observing the scientific terms that

could compromise the students' understanding due to the complexity involving technical terms. Based on this analysis, a minidictionary was developed to serve as support material for teachers and students, so that it can be used during research and discussion of the analyzed data in class.

In the next stage, the Activity Proposition Stage, two skills were selected for planning problem-solving activities. The problematizing approach started from storytelling with characters who, carrying out their day-to-day activities, come across a problem they cannot solve themselves. With the help of their teachers, the characters carry out experiments in the classroom that help in understanding the phenomena they encountered, where they observed the Life Cycle and cultivation of *Lactuca sativa* and the behavior of the species *Eisenia andrei* and *Eisenia fetida* in the face of a stressor agent. Understanding the situation that was discussed in the classroom, the characters return to their homes and use their knowledge to solve the problem initially encountered.

In the proposition stage, two of these skills were selected to plan activities based on the PBL methodology. The problematizing approach started from storytelling with characters who, when carrying out their daily activities, are faced with a problem that they cannot solve by themselves. With the help of their teachers, the characters carry out experiments in the classroom that help in understanding the phenomena found, where they observed the Life Cycle and cultivation of *Lactuca sativa* and the behavior of the species *Eisenia andrei* and *Eisenia fetida* in the face of a stressor. Understanding the situation discussed in the classroom, the characters return to their homes and use their knowledge to solve the problem initially encountered.

The species *Lactuca sativa*, *Eisenia andrei,* and *Eisenia fetida* were selected from ecotoxicological bioassays cataloged and widely used for environmental impact analysis (MORALES, 2004, ROMERO; CANTÚ, 2008, MISSURINI, *et al.,* 2018, EPA, 1996, AZEVEDO ; CORONAS, 2018, NIVA, 2019).

For the other BNCC competencies and skills granted in the first stage, activities that contemplated the phenomena addressed were suggested.

## RESULTS AND DISCUSSION

The BNCC skills that are possible to work on the concepts of ecotoxicology are shown in Table 1. For each selected skill, suggestions for bioassays, demonstrations, and the use of games were carried out to exemplify the impacts of contaminants on the environment.

As those are contents that involve knowledge of biology, chemistry, and the science curriculum component itself, the minidictionary developed (Table 2) is a support for research on technical terms of applied ecology, giving meaning to these terms with examples appropriate to the student's reality.

Krasilchik (2004) explains that students' difficulty in following classes can often be related to the excess of unknown words that are used in science classes, and there may even be a different interpretation from that explained by the teacher. The profusion of technical terms gives the student the idea that biology is a bunch of meaningless words and that these need to be memorized (KRASILCHIK, 2004).

The proposition is that the material is made available to students before the beginning of the class, so that, whenever one of these specific terms appears, the students can check them and, with the help of the teacher, interpret them. Thus, more technical concepts can be consulted by students whenever necessary.

The BNCC skills described as EF02CI04 and EF03CI10 were chosen, respectively from the second and third years of elementary school (Table 1), to approach the concepts of ecotoxicology. This way, in the second year, "the bioassay with lettuce seed germination" content was selected, and for the third year, "the bioassay escape test with earthworms" content was selected.

The stories were assembled to exemplify the experiments so that the use and manipulation of pesticides in the classroom are not necessary. The characters in those stories were inserted in a day-to-day environmental problem, and in the course of the story, for students to understand the phenomenon that is the focus of observation, it is suggested that a bioassay can be carried out in the classroom with the teacher's intervention. As the days go by, students in the classroom will be able to identify the similarities between the scenario presented in the story and the scenario they performed in class, being able to discuss their observations.

This prioritization of classes based on PBL brings as a consequence the principles of the scientific method, allowing basic education students to go through the stages of research, which are observation, questioning, construction of hypotheses, experimentation, and analysis of hypotheses.

Table 1 - BNCC skills that address concepts of Ecotoxicology and that can be worked on with pesticides and suggestions for bioassays.

| BNCC Skillset | Bioassays (experiments and/or demonstrations) |
|---|---|
| | 1st grade |
| (EF01CI01) To compare characteristics of different materials present in everyday objects, discussing their origin, how they are discarded, and how they can be used more consciously. | Conscious disposal of packaging with chemicals and pesticides. Here the teacher can explain the exposure effects that workers suffer when getting in contact with chemical compounds or their packaging with residues. The problem of worker intoxication can also be addressed. |
| | 2nd grade |
| (EF02CI04) Describe characteristics of plants and animals (size, shape, color, stage of life, the place where they develop, etc.) that are part of their daily lives and relate them to the environment in which they live. | Lettuce seed germination.<br><br>With such an experiment, the teacher can explain the effects that pesticides can cause in the embryonic development of the seed, which can affect the plant and its vital functions.<br><br>The interesting thing is that lettuce is a food present on the plate of a large part of the population, so the professor can speculate: If the pesticide affected the plant when we ingest it, will we be affected?<br><br>And, the plant is part of the environment, being a source of food in a food chain, which can affect other animals. |
| | 3rd grade |
| (EF03CI10) Identify the different uses of the soil (planting and extraction of materials, among other possibilities), recognizing the importance of the soil for agriculture and for life. | Escape Test with Worm<br><br>Earthworms are annelids that live in moist soils rich in organic matter, so they release humus (making the soil humus). This substance leaves the soils suitable for plantations, that is, rich in nutrients.<br><br>With this information alone, the teacher can already demonstrate the importance of such animals.<br><br>In addition, it can address the different types of soil, stressing again the importance of earthworms in order to have fertile soil.<br><br>With such experimentation, he can demonstrate that humid soils are more suitable for crops, which, in turn, are part of the trophic base of food chains, being vital to various living beings. |
| | 4th grade |
| (EF04CI07) Check the participation of microorganisms in the production of food, fuel, and medicines, among others. | In the fermentation of Saccharomyces cerevisiae, for example, as one of the final products, there is CO2 and, with this gas, we are able to fill a balloon. When this experiment is modified and pesticide is added, will the balloon fill with gas? What will the pesticide do to Saccharomyces cerevisiae?<br><br>In the example with Saccharomyces cerevisiae, used in the production of bread, for example, there would be a change in the final products in which this yeast is used.<br><br>This modification could occur not only in food but also in medicines and fuels, among other products in which microorganisms are used in production. Thus, the teacher can demonstrate how the use of a particular pesticide can be very relevant and, perhaps worrying, in people's lives.<br><br>In this class, topics related to catalase enzyme, and oxidative stress based on the suggested experiment can be addressed, but it is indicated not to use these technical terms due to complexity, in this case, to use them an adequate didactic transposition will be necessary. |

| | |
|---|---|
| | 5th grade |
| (EF05CI08) Organize a balanced menu based on the characteristics of food groups (nutrients and calories) and individual needs (activities performed, age, sex, etc.) to maintain the body's health. | Ecotoxicological tests using onions have been recommended by international environmental protection agencies to verify the level of toxicity of complex mixtures, a suggestion similar to that of lettuce seeds, which can also be used in this class.<br><br>Onion is a vegetable widely used as a seasoning for food, it consists of vitamins (A, B, and C), and mineral salts (Fe, K, Na, P, Ca), and if exposed to certain pesticides it can be affected by somehow (specify).<br><br>Thus, the teacher can explain the importance of onions and lettuce as food, in view of the nutrients and relating to the individual needs of each one in order to maintain the health of the organism, and performs the experiments referring to each of these foods that go identify in different ways the toxicity of the simulated environment. |
| | 6th grade |
| (EF06CI05) Explain the basic organization of cells and their role as structural and functional units of living beings. | With the extraction of DNA, the strawberry has a substance composed of fragmented cells, DNA, and lipid content of the cell membranes, but what happens to this substance when a pesticide is inserted? What will happen to the DNA? This is an experiment that can exemplify what pesticides can do to human body cells.<br><br>Cells are structural and functional units of all living beings, and DNA is responsible for storing genetic information in a compacted form in cells.<br><br>In this way, with such an experiment, the teacher can present such a structure in a way that complements explanations about cells (especially eukaryotic cells, which have a nucleus surrounded by a membrane, as in the case of strawberries). The class will be interesting, as they will be able to visualize a structure beyond the textbooks. |
| | 7th grade |
| (EF07CI08) Assess how the impacts caused by natural disasters or changes in the physical, biological, or social components of an ecosystem affect its populations, which may threaten or cause the extinction of species, change in habits, migration, etc. | Use of the educational game Daphnia World (CUMPIAN; BORGES, 2020).<br><br>With the game, students will be shown how it is possible that certain changes in the environment can extinguish species, causing a real imbalance in the ecosystem.<br><br>Changes in water quality can be observed by the physiological aspects of the bioindicator, in this case, the behavior of daphnias in the simulated environment will be observed and their mobility will be analyzed. |
| | 8th grade |
| (EF08CI16) Discuss initiatives that contribute to restoring environmental balance from the identification of regional and global climate changes caused by human intervention. | You can work with air pollution and use the experiment with paper filters that can be used to compare air pollution in two different environments.<br><br>You will need 02 coffee filters, 01 barbecue stick, and glue. They stuck it in one of the paper filters on the barbecue stick and left it exposed for 5 days outdoors meanwhile, the other paper filter stayed inside the closet in the classroom, isolated from air, dust, etc. After 5 days, both filters are checked and conclusions are drawn. |

| | |
|---|---|
| | 9th grade |
| (EF09CI12) Justify the importance of conservation units for the preservation of biodiversity and national heritage, considering the different types of units (parks, reserves, and national forests), human populations, and related activities.<br><br>(EF09CI13) Propose individual and collective initiatives to solve environmental problems in the city or community, based on the analysis of successful conscious consumption and sustainability actions | Demonstrations of conscious consumption and sustainability.<br><br>Use of the game Super Trunfo® Agrotoxics (CORRÊA; GOMES; LUZ; 2020)<br><br>Based on this game, individual and collective initiatives will be proposed on certain attitudes that one can have regarding conscious consumption and sustainability.<br><br>Based on this perspective, one can use the list published by Idec that listed several products classified as ultra-processed and that have pesticide residues and request that, based on the analysis of this list, students check in their homes which products their family uses. |

Table 2 – MiniDictionary of Ecotoxicology – basic concepts.

| Biologist's Dictionary | |
|---|---|
| Biological Concept | Definition |
| Bioassay | It is an experiment that is carried out to identify what happens to live organisms in environments contaminated by certain chemical compounds. |
| Bioindicators | They are living beings that are used to carry out experiments. They will indicate whether that environment is healthy or not. |
| Conductive vessels | They are tubes inside plants, similar to human veins, and serve to transport water and nutrients inside the plant. |
| Ecotoxicology | An area of science that studies the effects of chemical substances on the environment. |
| Environment | Is the set of natural conditions and influences that surround a living being or a community and that act on it/them. |
| Germination | This is what happens to the seed of the plant. When the seed is in a suitable environment for its survival, it will develop and the roots and the plant will begin to grow. |
| Ground control | Control soil is the soil that is natural, that is, uncontaminated soil, which will be used as a model when compared to soil contaminated by pesticides in the experiment. |
| Hypotheses | It is why you think it happens before you do the experiment, that's the hypothesis. After the experiment is performed you can tell whether your hypothesis was right or not. |
| Pesticides | Are synthetic chemicals used to kill insects, larvae, fungi, and ticks under the justification of controlling the diseases caused by these vectors and regulating the growth of vegetation, both in rural and urban environments. |
| Scientific method | It is a sequence of steps that must be followed to carry out an experiment. |
| Test soil | It is the one that will be prepared for the experiment, that is, it will be the soil that will be contaminated with the pesticide. |

**Proposition 1: - Life cycle and cultivation using *Lactuca sativa L.***

The focus of the class on the "life cycle of lettuce" is to explain the importance of this species as food, as well as to remember others that are the basis for human survival and to focus this information on the skill EF02CI04 from the BNCC. This skill represents the understanding that living beings have a life cycle, recognizing the basic care of plants and animals through their cultivation and breeding (PARANÁ, 2021a).

The species *Lactuca sativa* is a bioindicator for ecotoxicology and is widely used in bioassays, due to its rapid and homogeneous germination, it can be used to identify samples contaminated with some substance or complex mixture of liquids or solids solubilized in aqueous solution, where through inhibition of germination and by measuring the elongation of the radicles and hypocotyl, the toxicity of the medium can be determined (MORALES, 2004, ROMERO; CANTÚ, 2008, MISSURINI, *et al.,* 2018).

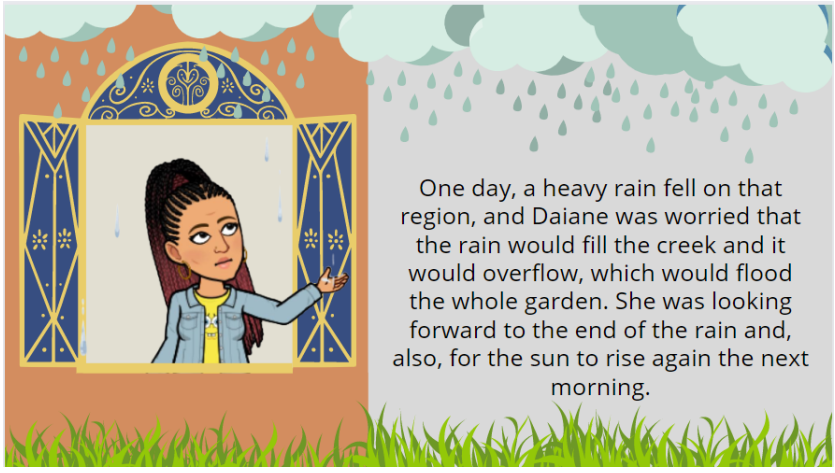
With the use of storytelling, the teacher can start the class by presenting the title of the story and the character. From this, during the story, he or she can emphasize the character's daily life and when he/she faces a problem. In the story "Daiane and the Stream", the character Daiane is faced with the difficulty of growing the lettuce 'seedlings' and asks herself: "what was in the water that damaged the growth of the plants?" (Figure 1). The teacher can finish the reading (storytelling) stage at this moment and, in the classroom, mediate a debate so that other questions related to the event experienced by the character are brought up by the students. After bringing up some hypotheses about the causes of the problem, students should be guided to carry out a survey telling them to each other.

Subsequently, the students, with their teacher, must carry out experimentation of the bioassay. The teacher needs to be clear that they will observe what would be equivalent to the control group in a research laboratory, given the difficulty in handling the contaminant in the school facilities.

The bioassay carried out in the classroom and described in the story follows the methodology described in Ecological Effects Testing Guidelines (EPA, 1996) OPPTS 850.4200. Germination/Root Elongation Toxicity Test from the United States Environmental Protection Agency - EPA, and from research by Morales (2004), Romero and Cantú (2008) and Missurini *et al. (*2018) which can be carried out in the classroom as the following instructions using lined plastic cups with a filter paper disc at the bottom (already cut to the size of the lid) adding a little water. In each cup, ten *Lactuca sativa* seeds should be sown, leaving enough space between them to allow the roots to elongate. And so that the water does not evaporate, it should be covered the cups with cling film and stored away from light. Each student can set up their experiment. For seven days, students can observe and record seed germination and plant development (MORALES, 2004, ROMERO; CANTÚ, 2008, MISSURINI, *et al.*, 2018).

With the germination observations and the proper records made, students will be led back to the storytelling and will realize what happens to lettuce seeds when placed in a stressful environment. From this moment on, the teacher must, again, mediate so that students can discuss the results observed in their experimental groups and the results observed in the story.

Students should be encouraged to work out the problem and suggest alternatives and solutions in order to solve the problem of the character in the story and think about the impact caused by the phenomenon observed in the environment.



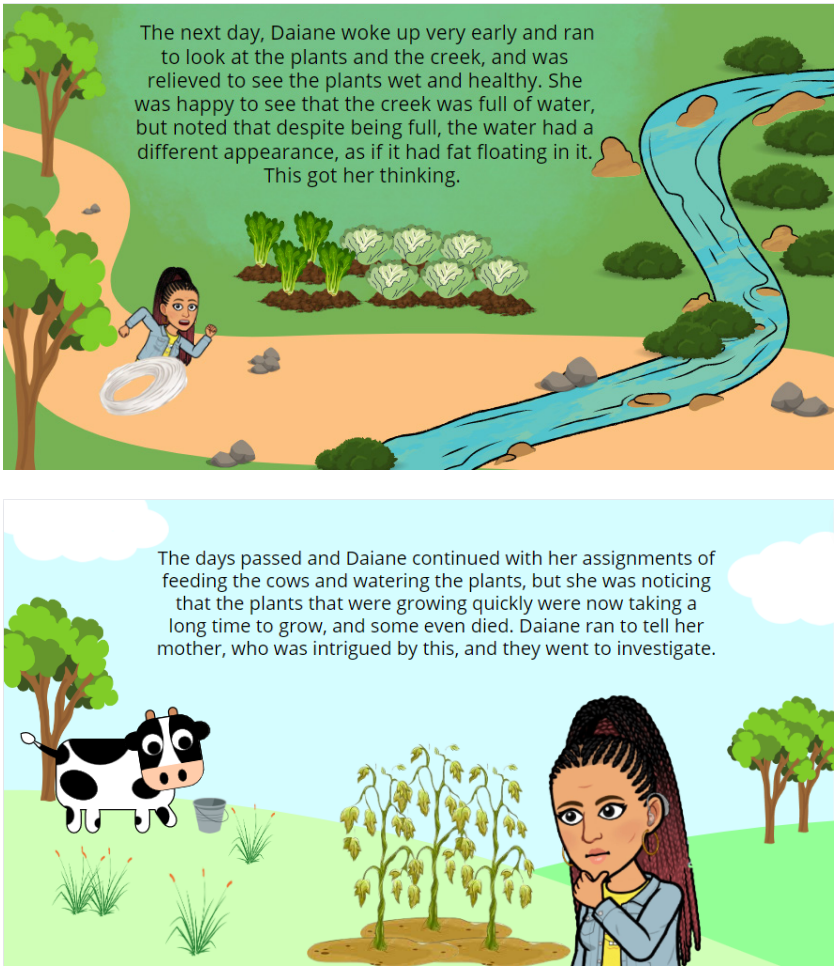



Figure 1 - Sequence and slides for the proposed class with a PBL approach on basic care for plants and animals through their cultivation and creation.

**Proposition 2: Observation of the behavior of the species *Eisenia andrei* (Savigny, 1826) and *Eisenia fetida (*Bouché, 1972)**

The class about earthworms will focus on identifying the importance of soil for agriculture and life, and for that, the leak test will be used to analyze the types of soil contemplating the skill EF03CI10 (ANDRÉA, 2010, AZEVEDO; CORONAS, 2018, PARANÁ, 2021b).

Escape tests with earthworms of the species *Eisenia andrei* and *Eisenia fetida* are alternative methods that help to identify the levels of toxicity of the environment, when being subjected to pesticides, they presented reactions such as changes in digging capacity, spiraling behavioral reactions, variations in production and cocoon weight; physiological effects and deformations, agitation, and what will be observed in the experiment, which is the rejection of contaminated soil (ANDRÉA, 2010).

In the story "Luiz and the Earthworms", Luiz, when looking for earthworms around his house, does not find them near the garden, even though there are perfect conditions for them to survive (Figure 2). From this point of reading the book, the teacher in the classroom should return to discuss the subject with the students, and encourage them to elaborate hypotheses about the possible reasons for the situation.

After making assumptions about the causes of the problem and raising the hypotheses, the bioassay begins. The bioassay experiment carried out in the classroom and described in the story is based on the technical standard of ABNT (2011) NBR ISO 17512-1 and the work of Azevedo and Coronas (2018), and Niva (2019). In class, the teacher will conduct the bioassay using an aquarium filled with healthy soil, where students will place worms they bring from their homes, which makes the activity more committed. This allows students to experience having to analyze the environment of their own homes or possible places to store the worm sample and promotes discussions to be carried out in the classroom. In this step, students should visualize the normal behavior of earthworms and should make notes of their observations.

From this point on, students should be led back to storytelling, and they will realize what happens to earthworms when placed in a stressful environment. Then, the teacher should moderate the discussions about the problem initially raised, and how the research carried out explained the reason why Luiz did not find earthworms in the surroundings of the home garden. At this time, students should be encouraged to solve this issue that has an impact on the environment.


Figure 2 - Sequence and slides for the proposed class with a PBL approach on the importance of soil for agriculture and for life.

## CONCLUSION

The use of PBL allows working on different skills, which favors the use of the scientific method and the construction of knowledge. The use of storytelling brings students closer to the phenomenon to be observed/researched and contributes to student participation in the research process. From the PBL onwards, the emancipation of citizens is favored, those who not only have access to knowledge but can appropriate it through their contribution to scientific production. This is because the PBL promotes the exercise/appreciation of curiosity, the collection of data about a certain fact/phenomenon and leads the student to defend a point of view, have autonomy, responsibility, care for their body and collective health, and above all, respect the planet and propose/recognize strategies for its conservation. The use of ecotoxicology content together with the formal science content favors the learning and understanding of science and technology in students' daily lives, contributing to the integral formation of citizens.

## CREDIT AUTHOR'S DECLARATION

ACDBK is responsible for the conceptualization, methodology, and supervision. HT performed the data curation, Writing-Elaboration of the original draft. ACDBK and HT jointly worked on the Writing-Revision and Editing.

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