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The Environmental Issue of Pesticides: The Problem-Solving Methodology in Elementary School

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ABSTRACT

In this article we present an experience done in an Elementary School (ES) using the Problem-Solving Methodology (PSM). The research was developed with the participation of 21 students from the 9th grade of a state public school in the city of Porto Alegre / RS. Thus, three problems were elaborated, considering different aspects of pesticides' environmental impact. The students were divided into three groups in order to solve these problems in a six-phase didactic sequence. This theme was chosen to contextualize the problems because Brazil is the worlds' largest consumer of pesticides. Furthermore, pesticides can be found as a theme in some science books for ES. For the data collection, we used the researchers' field diary, the students' written material, and the audio recording of the classes in which the PSM was applied. The observed and collected results show that the use of the didactic sequence allowed conceptual, procedural and attitudinal learning related to the approached PSM and scientific knowledge.

Keywords: Problem Solving; Elementary School; Environmental Education; Pesticides.

A Temática Ambiental Agrotóxicos: a Metodologia da Resolução de Problemas no Ensino Fundamental

RESUMO

Este artigo consiste na investigação de uma experiência de utilização da Metodologia de Resolução de Problemas (MRP) no Ensino Fundamental (EF). A pesquisa foi desenvolvida tendo como partícipes 21 alunos do 9º ano de uma escola pública estadual da cidade de Porto Alegre/RS. Assim sendo, três problemas foram elaborados, tendo em vista diferentes aspectos da temática ambiental relacionada a Agrotóxicos. Esses problemas foram solucionados pelos alunos em três grupos, em uma sequência didática que compreendeu seis momentos. O Brasil é o maior consumidor de Agrotóxicos do mundo, por isso esse tema foi escolhido para contextualizar os problemas apresentados. Além disso, o tema Agrotóxicos está presente em alguns livros didáticos de Ciências

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do EF. Para a coleta de dados, foram utilizados o Diário de Campo dos pesquisadores, a produção escrita dos estudantes e a gravação do áudio da aula em que os estudantes vivenciaram a MRP. Os resultados observados e coletados revelaram que a sequência didática utilizada possibilitou aprendizagens conceituais, procedimentais e atitudinais em relação à MRP e aos conhecimentos científicos abordados.

Palavras-chave: Resolução de Problemas. Ensino Fundamental. Educação Ambiental. Agrotóxicos.

INTRODUCTION

This research is a part of a developing Doctoral thesis, whose leading objective is to analyze how the implementation of didactic sequences that use the problem-solving methodology (PSM) contribute to the development of the main conceptions about the learning processes (Zabala, 1998) related to the environmental impact that pesticides can cause. We intend, therefore, to raise awareness among students of different levels and modalities of basic education (Ribeiro, et al., 2018a; 2018b) regarding this environmental problem. These articles have the same objectives, but different theoretical discussions and approaches, according to each stage of development of the research subjects. In the present article, we present an analysis of the experience of using PSM in an elementary school, working the theme pesticides in a critical environmental perspective.

In science teaching, the teacher should plan the class so that the student is able to relate to a new culture, a new scientific reality. That allows for the conscious practices that the scientific knowledges and notions bring, and suspends the rigidity of the discipline's usual contents, in order to help society. In addition, science education should be planned for citizenship education, promoting practical benefits for the people, society and the environment, so that the scientific implications for everyday life are recognized (Sasseron & Carvalho, 2011).

Farias (2005) explains that a good way for students to realize that chemistry and science do not exist only in industries and laboratories is to use everyday examples as a starting point for approaching content. The author also comments about the changes that occurred in textbooks. They started to adopt this type of approach, brought by the necessity of this type of methodology, considering the importance of illustrating or starting a content using examples taken from the reality of learners. Students need to understand the implications of science and technology for the society and the environment. For this to happen, teachers must understand that the target audience of their teaching practice are the students. What we teach should be good for them, and not for us, teachers, after all, learning should prepare for life, not only for exams, tests or the *vestibular* (Farias, 2005).

Mortimer (2002) talks about learning, taking into account the real problems of a community. He understands that efforts to change Brazil through the school are useless if we do not integrate this school space into the community. The author believes that by using students' real problems one can find out several of the community's setbacks, which could

be addressed in class. That means there is no reason to simulate hypothetical problems. In this context, if we tackle these problems that arise from our social, economic, cultural and environmental conditions, we have a singular condition as a Brazilian community to make a significant contribution to the world's education research community regarding scientific and technological problems (Mortimer, 2002).

Research on PSM developed with elementary school students has been contributing significantly to the improving quality in the teaching and learning process (Freire, Silva Júnior, & Silva, 2011; Finco-Maidame & Mesquita, 2017; França & Malheiro, 2017; Küll & Zanon, 2017). These authors affirm that this methodology was effective and significant for the participants of the investigations, causing them to reflect, to dialogue in a joint action, assisting them in their teaching and learning process.

The methodology used in the researches with elementary school students was vital for the students to be autonomous in the construction of their own knowledge, since it enabled them to develop the capacity to interact with everyday situations (Finco-Maidame & Mesquita, 2017; France & Malheiro, 2017; Küll & Zanon, 2017). The learning process is the core of the PSM, which aims at committing the students to the process of knowledge building. This process comes from the student-teacher interaction in which the teacher acts as mediator and not as the knowledge keeper.

We believe that PSM can lead students to be able to face day-to-day situations, evaluating them through the conceptual models and through the procedures of science itself. According to Pozo and Crespo (1998), there is a large number of daily situations that present problems related to the functioning of nature and technology. Humans are constantly in contact with scientific objects and products, but they understand and know little about their functioning.

Lipman (1995) emphasizes the impossibility of believing that students can learn to think better through an educational process that little stimulates them to think, emphasizing that many teachers refuse to reformulate their lesson plans, because according to such teachers it would be a vain effort to improve the skills that students should have brought to the classroom.

For Zabala (1998) learning is not just copying or reproducing reality. It means integrating existing knowledge with new ones, modifying them and establishing relationships. As the author sees it, the relationships between teachers, students and the content in the teaching and learning process overlap with didactic sequences, since teachers and students have a certain degree of participation in this process, not like in the traditional teaching process, characterized by transmission, reception and reproduction of knowledge. Thus, based on the concept of constructivist learning, the author presents the following types of learning: conceptual (What should be learned?); procedural (What should be done?); and attitudinal (How one should act?). About the conception of learning, the author states that it is not possible to teach without keeping to how students learn. We should focus on the particularities of the learning processes of each learner, which are different in many ways (physical, emotional and cognitive, for example).

He ascertains that "when one explains in a certain way, when one requires a concrete study, when one proposes a series of contents, when one asks for certain exercises, when one orders activities in a certain way, etc., behind those decisions one hides an idea about how learning takes place" (Zabala, 1998, p.33).

Concerning our environmental research theme, Gewandsznajder (2015a) explains that plantations are commonly more susceptible to an insect attack than natural vegetation. With the removal of the original forest, many insect predators disappear, causing an environmental imbalance, thus jeopardizing agriculture. Currently, the method most used by small, medium and large producers is chemical control, which is the use of chemicals, called pesticides (insecticides, fungicides, bactericides, herbicides etc.) which aim to control pests and diseases. Pesticides have a fast and efficient action; however, they cause the development of populations of resistant insects, the emergence of new pests or even the resurgence of others, the occurrence of biological imbalance, harmful consequences to man and other animals, and they can also contaminate the different environmental matrices.

We believe in an education that can lead students to a critical and reflective knowledge, and that can really make studies in environmental education relevant to society, to critical environmental education and transformation, and to emancipatory education (Tozoni-Reis, 2007). This educational principle has a collective, dynamic, complex and continuous character of social awareness and participation, articulating theory and practice, marked by the interdisciplinary approach (Pombo, 1994).

Considering the environmental problems related to pesticides and a pedagogical proposal that may be able to improve the quality of the teaching and learning process, we performed an activity, uniting the Portuguese class and the science class with a critical environmental perspective (Guimarães, 2004; Loureiro, 2005; Tozoni-Reis, 2007), aiming at applying the PSM and contextualizing our work with the environmental theme of pesticides. The objective of this study is to evaluate the contribution of the didactic sequence applied to the development of the main conceptions about learning processes (Zabala, 1998) related to the environmental problems that pesticides can cause.

THEORETICAL BACKGROUND

As a result, from the largely capitalist mode of production in which the world finds itself, environmental degradation is steadily intensifying in our society. Therefore, the need for a critical environmental education arises, in order to generate proposals and projects to guarantee theoretical rigor and reflective deepening on its foundations, so that it can really make the research in environmental education relevant to the community (Teixeira, Neves, Silva, Tozoni-Reis & Nardi, 2007). This need for environmental studies, which really fosters a critical and reflexive thinking in people, becomes even more necessary in the school space.

According to Tozoni-Reis (2001), the origin of environmental educational action is the movement to become fully human by the appropriation and/or critical and transformative transmission of the historical and concrete totality of human life in the environment. The author contends that this environmental education process mediates the appropriation by the subjects of the fundamental qualities and capacities for responsible transforming actions in the environment in which they live (Tozoni-Reis, 2001).

Researchers in the field of education have brought valuable contributions by giving meaning and re-signifying the foundations and concepts of environmental education, in the sense of providing an epistemological sedimentation in the process of construction of its theoretical field (Guimarães, 2004; Loureiro, 2005; Tozoni-Reis, 2007). These authors, in their works, problematize and contextualize environmental education in a critical and dialogical perspective.

Tozoni-Reis (2007) explains that an important approach in the understanding of environmental education is to understand it "as a political process of critical and reflective appropriation of knowledge, attitudes, values and behaviors that aim at the construction of a sustainable society in the environmental and social point of view" (p.180).

In this context, critical education is situated on the horizon of the political action of education if it is focused on social transformation, as Guimarães (2004, p.25) reflects: "I felt the need to re-classify environmental education as "critical", because it is necessary to distinguish an educational action that is capable of contributing to the transformation of a reality that, historically, has put itself in a serious socio-environmental crisis."

In this line of thought, Teixeira et al. (2007) affirm that "research in environmental education must be mediated by reflections of its foundations and concepts, so that it does not end up legitimizing the contradictions produced by the capitalist mode of production" (p.3). The same authors believe that only through a rigorous and dense reflection of the theoretical principles of environmental education, will we be able to problematize educational practices and theoretical tendencies, "providing the reflection of these contradictions and, consequently, pointing to the need for qualitative change in the processes that determine the environmental problem that materializes in social organization in concrete situations and in a concrete way" (Teixeira et al., 2007, p.3).

We believe that the primary purpose of the school is to develop the whole formation of the student, through a learning that privileges experiences lived by the students and makes them reflect deeply on the reality that surrounds them, thus contributing to them becoming critical and reflective citizens. A critical and reflective environmental education becomes especially relevant when one considers the social context in which students live.

We have already discussed in this work that the PSM can converge to the integral formation of the student, because in this type of method the teacher is not the center of learning, but the guide of the students' learning process. The teacher is no longer the "master of knowledge", which gives students the opportunity to develop cognitive, motor,

affective and attitudinal aspects, necessary for the awareness about the risks caused by pesticides.

Considering our theoretical review on critical environmental education, we understand that awareness is more important than the appropriation of knowledge about pesticides. This awareness will only be internalized when the students reflect on this acquired knowledge and manage to relate them with the political, social, economic and environmental aspects of the dangers that these chemicals can cause to humans and the environment.

RESEARCH METHODOLOGY

We developed a qualitative investigation, using the case study research to work with a very specific social scenario. Lüdke and André (1986) explain that case studies present some vital characteristics, some of them being that they: aim at discovery; emphasize interpretation in context; seek to portray reality in a complete and profound way; use a variety of sources of information; seek to represent the different and sometimes conflicting points of view present in social situations; may be similar to other cases, but they are also distinct, for they have a specific, unique and particular interest, and represent a potential in education.

The most common case studies are those that focus on a unit. This unit may be either an individual (single and singular, as is the "clinical case"), or a conglomerate, in which several studies are conducted simultaneously (several individuals or several organizations, for example). Based on these methodological assumptions, the case study described in this work was developed with 21 students from the 9th year of elementary school, day shift, of a state public school in the city of Porto Alegre/RS in November 2015. All participants or persons responsible signed a Free and Informed Consent Form. However, since the research here described began before the implementation of the National Health Counsil's Resolution 510, in April 7th, 2016, it is not registered with the Research Ethics Committee.

The data were collected through the recordings on the researchers' field diaries (Porlán & Martín, 1998), the written productions produced by the students, the questionnaires applied and the audio recording of the classes, and their contents were later analyzed. This methodology is characterized as one of the classic procedures for interpreting textual materials. According to Bardin (2010), content analysis is "a set of communication analysis techniques that uses systematic procedures and objectives to describe the content of the messages", and also allows "the interference of knowledge regarding the conditions of production (or, possibly, reception), which is based on indicators (quantitative or not)" (p.40).

PEDAGOGICAL PROPOSAL

Having elementary school students as subjects of the research, we analyzed an experience of the use of PSM, contextualizing the subject pesticides, working with their description and use, and some possibilities for these chemical substances. The students experienced the PSM in the video room of their educational institution. So that all of them could take part in all the phases of the study, the experience occurred in a single encounter of five continuous periods. We used a didactic sequence that covered six phases, as shown in Table 1.

Table 1
Didactic sequence.

Phases	Activities
I.	Students' introduction to the topic through excerpts from a motivational video ("*O veneno está na mesa 1*" ("The Poison is on Table 1") available at https://www.youtube.com/watch?v=8RVAgD44AGg) (Tendler, 2011) and the researchers' explanation of the environmental impacts that pesticides can cause, facilitating discussion with students about the contents and contexts present in the problems to be solved;
II.	Organization of the work teams in three groups of seven people, followed by the reading and analysis of the problems, which were presented during the discussion phase;
III.	Discussion within the groups to elaborate working hypotheses and search through the materials available, which included the sixth and seventh year elementary school didactic books indicated by the National Book of Textbooks – 2017 ("Programa Nacional do Livro Didático", Gewandsznajder, 2015a and Gewandsznajder, 2015b) and the chemistry book of the 1st year of high school indicated by the National Program of Didactic Books – 2015 ("Programa Nacional do Livro Didático", Santos & Mól, 2013);
IV.	Preparation of the presentations with the resolutions;
V.	Presentations of the resolutions;
VI.	Collective debate, in which the teachers carried out a survey on the main models of resolution and emphasized the fundamental concepts discussed.

The proposed problems can be categorized as: school themed, since the goal is to develop scientific concepts, procedures and attitudes, and that enable the understanding of everyday facts; semi-open, since the statements partially exhibit the indispensable means for their resolution; qualitative, since the students can use scientific concepts and theories, without needing calculations or mathematical reasoning; and theoretical-practical, because they admit experimental methods and theoretical reasoning to solve them (Pozo & Crespo, 1998). We emphasize that the semi-open and qualitative problems allow the students themselves to incorporate ideas and strategies in order to define and solve the task.

We decided to elaborate three problems in order to further the study of the contents of the subject pesticides (Table 2).

Table 2
Problems about pesticides developed for elementary school.

Problem 1: *Earth's population is at around seven billion people! Feeding all of these people is a big challenge. Especially if we consider that everyone has the basic right to fulfill their basic nutritional needs. In this scenario, over the recent decades, food crops have increased considerably. This was made possible mainly because of the results obtained in the fight against agricultural pests. It is undeniable that pesticides play a vital part in this fight. However, the application of these chemical products has been so intense that a part of them persists in the environment and intoxicates the workers who apply the pesticides to the crops. Research about the definition of pesticides and the health problems that they might cause to the human body. Which cares should the farmer take when using pesticides?*
Problem 2: *A large number of Brazilian municipalities has agriculture as their main economic activity. Not only monocultures, which use large tracts of land for the cultivation of a single type of crop, but also polycultures, usually smaller, family-run, multi-crop plantations. Make an investigation to explain why polycultures use less pesticides than monocultures and which environmental problems pesticides can cause. Also describe another way of reducing pesticide use in agriculture.*
Problem 3: *It is estimated that 90% of Brazilian "organic" farmers are small producers linked to NGOs and cooperatives. The remaining 10% would be large producers linked to private companies. For having higher costs and, therefore, higher prices, "organic" produce is usually marketed in higher income regions. When consuming "organic" food is not possible, a good option for those who want to lower their pesticide consumption is to buy fruits and vegetables that are in season. Produce that are out of season usually get larger quantities of pesticides. In this context, describe some ways to select produce with less pesticide residues and explain how biological control can reduce the use of these chemicals.*

After concluding the didactic sequence, to close the activities, we applied a questionnaire with the objective of evaluating the contribution of the PSM in the students' understanding of the contents, as well as the development of the abilities of analysis, reasoning, classification, research, decision-making and information organization. Such abilities are fundamental to educational objectives (Lipman, 1995). Since the entire activity took place in one single encounter, all 21 students answered the questionnaire.

THE SIX PHASES OF THE DIDACTIC SEQUENCE

We used the school's video room because it had everything needed to make audio-visual presentations and it could accommodate all of the students. The science teacher and the Portuguese teacher explained to the students the research's objective, that the audio recording would only be used for the research and that their identities would be kept secret. Afterwards, the researchers asked the class what they knew about pesticides. That marked the beginning of the **Phase I** of the didactic sequence. One of the students said it was to keep bugs from reaching the plant. The science teacher insisted, asking what would happen to a bug that got to the plant that had pesticides. One of the students said that the bug would die. From that answer, the teacher asked the students what type of substance kills a living being. The students got to the conclusion that pesticides are a

poison. The teacher then asked if it would be good or bad if someone put poison in their food. In unison, the class replied that it would be bad. The teacher asked further about what are pesticides. One student said that pesticides are poisonous products that kill plants, harming nature. Another student said that pesticides are products used in agriculture to improve the plants, and a third said that pesticides are toxic products with the intention of killing plants. The debate went on and one student replied that pesticides are used in plantations in order to protect food from animals and bacteria. The next student said that they are products used in the crops so that the food can evolve faster, which might harm plants, fruits, soil and humans.

Even though some answers lacked some more precise information, or even because of a lack of more precise vocabulary, what could be observed through the answers given was that some of the students have a notion about what are pesticides, that these substances are not good to living beings and to the environment, and that they realize that food without these chemicals is healthier for human consumption.

By asking so many questions to the students, what the teacher intends is to lead the student, using conducting questions, to reflect, to come to their own conclusions, to arrive at a consensus. When acting like this, the teacher is not a simple information conduit, but rather a knowledge producer who is in tune with the student, directing, conducting the processes of teaching and learning, and stimulating reflection.

Thus, the researchers started the work and, through conducting questions, activated the students' previous knowledge about pesticides, looking for socially-produced concepts about the theme, information which the students knew to a greater or lesser extent. This previous knowledge activation is important to a conceptual content learning, so that during the proposed activities the existing concepts can be improved. The students are given the opportunity to appropriate what is being taught and thus build their own knowledge (Zabala, 1998).

Paulo Freire (1921-1997) states that "knowing how to teach is not simply transmitting knowledge, but creating the possibilities for its production or construction". The teacher should not reward content memorization; content should be contextualized. In this research, for example, the methodology used pesticides as context, a topic very close to the students' reality. We started from the students' life experiences and world knowledge, from their participation, which brings us to believe that the students' motivation observed throughout the whole experience is related to the previously described procedures.

The students showed to be very motivated and interested during the stage of questions and answers, since they actively participated in it. Once it was concluded, the researchers used a PowerPoint presentation to start explaining the methodology and the topic to be worked, which were: **"Problem solving and pesticides"**

Soon after those explanations we showed some selected excerpts from the video "*O veneno está na mesa I*" ("The poison is on the table I"). The students showed a lot of interest and were attentive to the information brought by the film. The researchers paused the film to make some comments and explanations about it.

The video "*O veneno está na mesa I*" is a documentary by Sílvio Tendler and it shows reports by experts and farmers about the harm that the overuse of pesticides can do to humans, animals and the environment. The documentary is very impressive, because it not only shows various diseases caused by these chemicals, but also denounces the atrocities committed during the Second World War and during the Vietnam War with the use of chemicals. It also comments on alternatives to a healthier and more sustainable agriculture, which preserves nature, farmers and consumers.

Phases II and III: The researchers asked the students to form 3 groups of 7 people each. Once the groups were organized, the teacher handed the problems to be solved and the material available for consultation. Each group got one of the three problems. The researchers read the problems with the students to explain them and answer any questions the students might have.

Phase IV: During the problem-solving phase, the researchers walked around and helped the students with some doubts that rose. We noticed a great interest about the proposed activity, noticing that the students really discussed pertinent questions to the problems they received.

Based on the initial discussions on pesticides, on the presented video and on the consultation materials available, the students reacted in a positive and motivated way to solve the problems. They discussed between themselves, brought examples from their lives, sometimes disagreed, but ended up arriving at consensuses. Working with problem solving in science education allows the development of the students' creative thinking, as well as the capacity to learn how to learn, which, in turn, allows the students to become reflective and critical learners.

We believe that, in science teaching, the PSM is an essential perspective to the students' learning improvement. This belief brings some researchers to award a role of "the thinking act's engine" (Freire, Silva, Júnior & Silva, 2011; Vasconcelos, Lopes, Costa, Marques & Carrasquinho, 2007) to the PSM. Scholars consider that the PSM has a primordial aspect in the scientific activity and, in the same way, becomes a decisive intellectual process for the learning of sciences (Pozo & Crespo, 1998; França & Malheiro, 2017; Küll & Zanon, 2017).

After they solved the problems, the students went to the computer laboratory to search for images related to their problems. The purpose of finding these images was to make a poster that would aid them in the oral presentation of the problems' resolutions. During the making of the posters, we noted that the images were adequate to each problem and that there was a great concern about making the poster so that they would facilitate the explanations of their resolutions.

We emphasize that the use of diverse didactic resources is an important tool to aid learning. "With the use of didactic-pedagogical resources, we aim at filling the gaps that traditional teaching usually leaves and, therefore, besides exposing the students to the content in a differentiated way, turning them into active participants in the learning process" (Castoldi, 2006, p.985). Making posters is, then, a way for the students, mainly

those in elementary school, to get away from their daily routine that uses the blackboard, pen and paper. It allows them to use their imagination, creativity and, as is the case with the chosen methodology, orient themselves to their oral presentation with the purpose of explaining the resolutions of their problems.

With the making of the posters, we could observe that there was interaction between the students. There was dialogue, exchange of ideas, reflection about what they were doing and critique about the resulting posters, produced without assistance from the teacher, only classroom orientation.

Phase V: With the posters ready, we started the oral presentation of the problems' resolutions. Group 1 went to the front of the room and a student read the problem out loud. With the poster's help, each member of the group answered, in a clear and adequate way, the questions that were asked. The group was able to realize that the pesticides can cause serious harm to human health, and that in order to mitigate this problem it is recommended: training the users of these products, using appropriate equipment and clothing (masks, boots, gloves, etc.), selecting the products carefully, administering the correct dosages, storing and disposing the packages the right way, and, mainly, practicing organic agriculture.

We understand that pesticides are used to increase agricultural productivity. By using them, lots of produce loss is avoided, mainly reducing damage by bugs, weeds and fungi. However, the students understood and reflected about the great care which must be taken when applying and handling these substances in order to reduce the environmental impact they might cause. Reflecting about the care with pesticide handling and having conscience about the serious health problems they can cause is fundamental for this environmental teaching to become meaningful to the students (Teixeira et al., 2007).

Group 2 started in the same way, positioning themselves in front of the class, reading the problem for them, and then they started explaining. They understood how dangerous these substances are to living beings in general, not only to the ones that are harmful to the plantations, but also to others. Understanding that pesticides also harm insects that make pollination and predators that feed on the organisms that attack crops (the disappearance of these predators makes it necessary to use even more pesticides) made them understand the real threat that pesticides pose to the environment.

Thinking critically and reflexively is necessary for environmental studies, so that the students learn to relate humans' practices with their effects in nature. This goes towards the critical environmental approach that we defend: "So, if our approach to environmental education is fundamentally concerned with the socio-environmental aspects of human relations, understanding them in a critical, transformative and emancipatory way", "the main objective" of research "in environmental education as we understand it is to produce knowledge about critical educational processes with a commitment to transform social and environmental relations in the perspective of emancipation". We contend that "if environmental education is the environmentalization of education, defended here as critical, transformative and emancipatory, the task of environmental education research

is to produce knowledge for *this* process of environmentalization of education in this perspective" (Tozoni-Reis, 2008, p.159).

Group 3 proceeded in the same way as the others, reading their problem and explaining, with the aid of the poster, the resolution they found. They commented that a part of the population is aware of the environmental problems and are opting for natural products. The science teacher intervened, saying that these foods have higher prices than traditional ones, maybe because of the lack of government incentive, or maybe because there are still people who are not aware of the dangers of pesticides, so they do not look for organic food. The students also spoke about the environmental, social and health benefits of organic farming.

Phase VI: Once the presentations finished, the researchers discussed the work the class had done during the activity. The Portuguese teacher asked the students if they had ever worked with the PSM before. The students answered that it was the first time they had worked this way and with two teachers in the classroom. The science teacher made some comments about their presentations, highlighting the positive aspects and the aspects to be improved, explaining them. He then came back to the question of whether pesticides are good or bad, and the students answered that they are bad, to which the teacher asked the reasons. The students said that pesticides are prejudicial to health and the environment. So, the teacher asked to whom the pesticides are good, and one student said that they are good for the government, because they generate taxes.

By the students' answers, the resolutions to the proposed problems, the field diary's notes and the audio analysis, we realized that, at several points, the students were able to link the processes of environmental preservation with the social processes in the world view, in the form of intervening in real life, and in existing in nature. This approaches Tozoni-Reis' (2001) assumptions that explain that one of the goals of environmental education is to enhance the international activity of social practice, which impresses the individual development of a social character in the relation with the environment, making this human activity fuller of social practice and environmental ethics. "This activity requires a systematization through a methodology that organizes the processes of transmission/appropriation of critical knowledge, attitudes, and political, social and historical values" (Tozoni-Reis, 2001, p.42).

EVALUATING THE DIDACTIC SEQUENCE

The students' evaluations of the activity were collected in the questions 1, 2 and 3 of the questionnaire that was applied after the didactic sequence. All 21 students who participated in the research answered the questionnaire.

In the first question, the students were presented with some statements that relate to skills and concepts that we wanted to develop or improve with the PSM. In figure 1, we show the students' degree of agreement with the presented sentences.

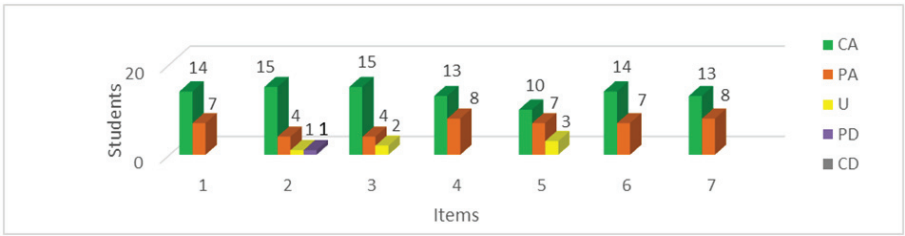

Figure 1. Students' degree of agreement to the sentences 1 to 7 (1- I developed my investigative skill in the search for resolutions to the problem; 2- I developed my ability to organize information; 3- I developed my ability to reason; 4- I developed my analytical skills; 5- I developed my classification ability; 6- I developed my ability to solve problems and make decisions in face of real-life problems; 7- The problem solving methodology contributed to the learning of Nature Science knowledge). Legend: (CA = completely agree; PA = partially agree; U = undecided; PD = partially disagree; CD = completely disagree).

The analysis of figure 1 shows that, in items 1, 2, 3, 4 and 5, which relate to the development of research, reasoning analysis and classification skills, respectively, most students gave favorable responses to the contribution of the PSM to their development. Lipman (1995) recognizes that these four ability groups become relevant to educational goals, suggesting that students can strengthen and improve them through activities proposed by classroom educators. We observed that only one answer was unfavorable towards the contribution of the methodology, that is, the general result points to the effectiveness of the teaching proposal in the development of said skills, in the students' opinion. In item 6, all 21 students agreed that the methodology contributed to the development of their ability to solve problems and make decisions when facing real-life problems. In item 7, which refers to the students' impressions about the contribution of the methodology towards the learning of nature science's knowledges, all answers were favorable to its application. We believe that the results reflect the students' involvement and participation during the proposed activity and that the work that was done in the groups contributed to the students' development.

The questionnaire's second question asked the students to report what other skills and knowledge they believed to have developed with the PSM. An analysis of the students' answers led to nine participants who reported to have developed the ability to work in groups, to respect others' ideas and opinions so that the team could reach a consensus: *"I developed my ability to work in groups..."*; *"To be more accepting of diverse opinions, so we could arrive at a consensus"*; *"I developed the way for working in groups because my group was able to work as a team and to present as a team"*.

Still on the analysis of the second question, ten students wrote about the knowledge they developed regarding pesticides and the ingestion of healthier foods without the use of these substances: *"My group and I acquired great knowledge about pesticides, and also about how to be warned about those things"; "I learned many things about fruits that I had no idea, for example, the pesticides that are in the fruits and that cause diseases"; "In this Portuguese and science class I learned about foods with pesticides, that we should wash them well and peel as well"*. The third question of the questionnaire was as follows:

Did you enjoy working with the PSM? Why? Analyzing the students' answers, we verified that all 21 answered that yes, they liked working with the PSM: *"Yes, because it brought a lot of knowledge, a lot of things I did not know and today I learned"; "Yes, because with it I learned a content I did not know and I exercised my mind with the activities"; "Yes, because it brought me knowledge of things I did not know"*.

Thinking about the same question, one student said that the PSM can help students to create tools to build their own knowledge: *"Yes, because that opened up the possibility of understanding how pesticides can harm the life of a living being"*.

Another seven students used terms such as "different", "new", "breaking the routine" and "creative" about the PSM, showing how little known this pedagogical proposal is: *"Yes, I liked because it was a different activity that I would like to do more times and my group could work as a team"; "Yes, because it was something different from our previous works and from a different point of view"; "Yes, because it was a class different from the others, with other type of content, that is why I liked it, I managed to get more knowledge"*.

The fourth question was related to a self-evaluation regarding the proposed method, the PSM. This question asked the students' degree of agreement to some sentences, using the following scale: 1 = CD completely disagree; 2 = PD partially disagree; 3 = U undecided; 4 = PA partially agree; 5 = A agree. The calculations of the value of agreement was determined by summing the number of times the option was chosen, multiplied by the score assigned to it, and divided by the total number of answers.

Analyzing the chart 1, we observed that most of the students agreed that the problems were easy to understand and had an accessible language. However, they still needed to research in order to resolve the problems and to arrive at adequate strategies. The analysis also shows that the students did not have a lot of difficulties to comprehend the proposed problems.

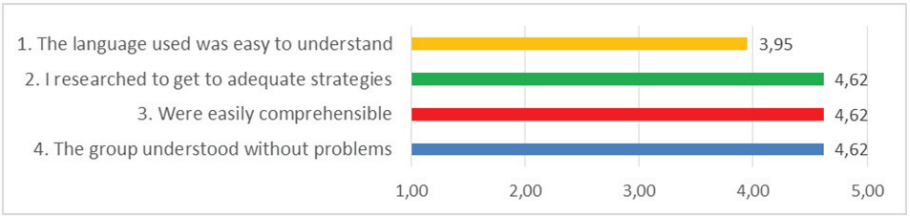

Chart 1. Students' opinions about the proposed problems.

Chart 2 shows the students' degree of agreement about working with PSM. As can be seen in this chart, the students agree that the work contributed towards their learning about the pesticides environmental theme. They considered that the time was sufficient to the problems' resolution and that the methodology used in this research contributed to their learning, possibly being meaningful for a better understanding.

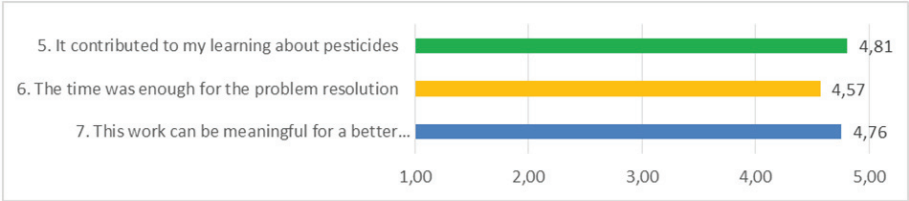

Chart 2. Students' opinions regarding the work with PSM.

Regarding their self-evaluation, chart 3 shows that they collaborated with the other students in the group, actively helping in the resolution of the proposed problem, and that they felt motivated to deal with the suggested activity. They also believe to have acquired new knowledge during the phases of the PSM.

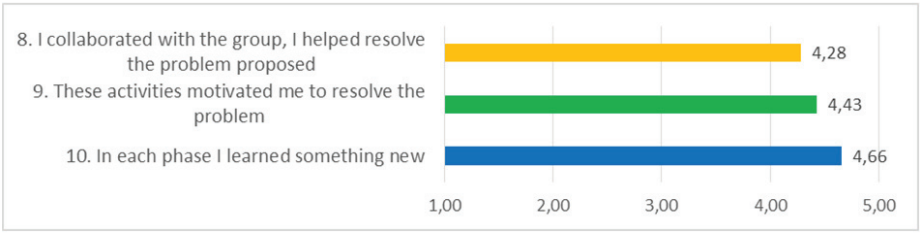

Chart 3. Students' opinions about their conduct in the PSM class.

What we can see in this chart is that nearly all of the students registered answers favorable to the contribution of the PSM to their improvement in the pesticides environmental theme, and they noticed the methodology's contributions towards a better understanding of the concepts worked in class.

CONCLUSIONS

The purpose of this work was to investigate the contribution of a didactic sequence implemented using PSM in order to develop conceptual, attitudinal and procedural knowledge related to the environmental problems that pesticides can cause, and to make elementary school students aware of this environmental problem.

We believe that a school that presents "ready" and decontextualized knowledge is not enough if we are aiming at a society in which we have critical and reflective citizens and that, in this way, can interfere in the conscious and just development of humanity, with the aim of seeking an improvement in the quality of life. It is necessary for the students to learn how to learn, acquiring new knowledge and abilities, thinking, reflecting and being critical in relation to their objects of study. Therefore, we believe that PSM is a methodology that presents considerable potential to achieve these objectives.

We chose to contextualize the PSM with the theme pesticides because Brazil is the largest consumer of pesticides in the world. This contextualization also helps emphasize the importance of the environmental education in the school as a tool for awareness, reflection and critic (Tozoni-Reis, 2001). This aims at a change in behavior, seeking sustainable development and environmental preservation.

We also took notice of Zabala's (1998) main conceptions about the learning processes. We favored conceptual learning through the reflective handling of the specific content in problems that challenged the groups. Thus, the elaboration of concepts enables the learners to experience knowledge, to elaborate generalizations, to analyze regularities, and to re-signify and associate this content with a scientific, creative and productive perspective. The procedural learning took place in the dialogic, participatory and shared educational concept, which aimed at increasing the reflective capacity of the learners about the reality that surrounds them, showing a know-how that includes decision-making and the accomplishment of a chain of actions. The attitudinal learning can be found on the daily school life, encompassing values, attitudes, norms and positions that intervene in the relations and interactions of the school community through a responsible educational view.

Our analysis show that the implemented didactic sequence pushed the students towards conceptual, procedural and attitudinal learning, as can be seen in their actions throughout the activity. We are convinced that, during our investigation, the students profited from the PSM. That can be seen in the written reports with the resolution of the problems, in the preparation of the posters, in the groups' oral presentations and in the closing of the activity done by the researchers, all of which corroborate the understanding and construction of the knowledge on the part of the students, who understood reflectively and critically that the pesticides are a danger to the environment and, consequently, to the health of living beings.

AUTHORS' CONTRIBUTIONS STATEMENTS

C.G.P. and T.D.M.S. oversaw the project. All the authors conceived the idea presented. All authors developed the theory. D.C.A.R. adapted the methodology to this context, created the models, performed the activities and collected the data. D.C.A.R. analyzed the data. All authors discussed the results and contributed to the final version of the manuscript.

DATA AVAILABILITY STATEMENT

Data supporting the results of this study will be made available by the corresponding author, D.C.A.R., upon reasonable request.

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