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Teaching Chemistry Proposal for Integrated Agricultural Technical Course on the Theme of Contamination by Pesticides and Heavy Metals in a Water Reservoir

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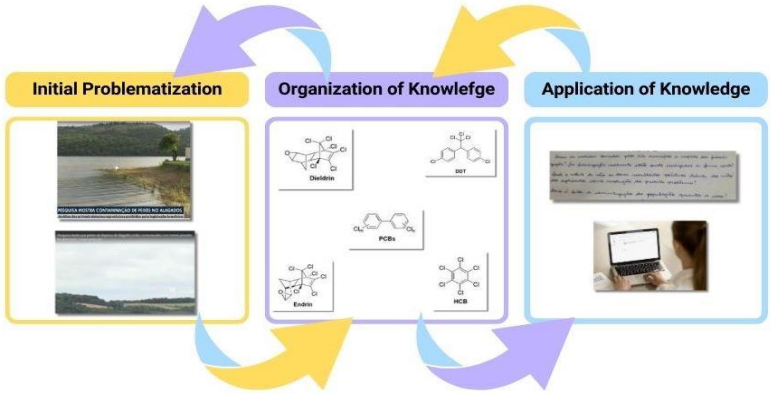
This paper presents a proposal for Teaching Chemistry (TC) with a focus on Environmental Education (EE) using the three pedagogical moments (3MP) as a didactic strategy and a local theme on the problem of environmental contamination of a water supply reservoir by pesticides and heavy metals. The research was carried out with vocational students from the Integrated Agricultural Technical Course at a public school in the city of Ponta Grossa, Paraná. The work used scientific articles, television reports, software for data collection and, at the end, the students were encouraged to produce an e-mail to send to the local authorities about the actions being taken to deal with the problem of contamination. The results point to the need for chemistry classes to effectively articulate local content and themes on environmental contamination, with a view to critically training agricultural technicians, which will enable them to reflect on their rights and duties as citizens. It was found that there was a significant improvement in the understanding of chemical concepts and criticality in relation to environmental problems. Thus, the use of the 3MP and an environmental theme would enable technicians to be trained as holders of scientific knowledge and professional skills in tune with the social and environmental reality.

Graphical abstract



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1. Introduction

In the Law of Guidelines and Bases of National Education (LDB) No. 9394/96 in Chapters II and III, Titles IV and V - A from article 36 to 42, with regard to high school professional education, youth and adult education and professional and technological education, in an integrated form or in a subsequent form for those who have completed high school, which will have access to technical professional training for a shorter period, where the individual is trained only for

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professional practice. In the integrated modality, the individual's training in regular secondary education is combined with the training of a technical vocational course aimed at training for professional practice [1].

In the State of Paraná, the Integrated Agricultural Technician Course Plan states that:

> "It provides graduates with the knowledge, skills and competencies necessary for professional practice and citizenship, based on scientific-technological, socio-historical and cultural foundations. The guiding principles of the Technical Course in Agriculture articulate Basic Education with Professional Education, from the perspective of integrating specific knowledge for the production of knowledge, assuming research as a pedagogical principle"[2].

Among the objectives set out in the same document in relation to the training of the professional Agricultural Technician, there are proposals directly linked to the inclusion of methodologies that make it possible to work in an interdisciplinary way with the compulsory contents connected with professional training and also training as a citizen:

> [...] To develop the student's theoretical/practical training, keeping them connected to their economic, social and cultural reality. Integrating the different spheres involved in the process (City Hall, School, Family and other official bodies) of building effective actions for the success of the student and their family. [...]
>
> [...] To promote the production of knowledge, linking the axes of science, society, technology and work through the development of scientific research. To train critical, reflective and ethical professionals who are capable of participating in and promoting change in their field of work, in their community and in the society in which they operate [...] [2].

The Integrated Agricultural Technician Course Plan also includes an area for studying agrochemicals, where the proposed objectives are related to the study of concepts about herbicides, fungicides, inoculants, chemical fertilizers, classification in terms of mode of action and application, toxicological classification, and soil and water conservation [2].

It can thus be seen that the documents proposed for the training of new technicians are concerned with social and environmental aspects related to scientific knowledge, as well as the development of criticality in relation to different themes that will form part of their curriculum for a broad education. It should be remembered that Brazil is considered the breadbasket of the world and these technicians will be at the forefront of the entire production chain involving agriculture. It is therefore important that their training offers them different strategies, so that, when they are working, they can be critical of their work and help the country socially and environmentally. In this way, it is believed that working with topics involving water and its contamination could effectively contribute to this critical training in technical courses.

Water, a vital resource for the survival of all living beings, continues to be an object of growing concern for the planet, affecting the environment, human health and sustainable development. In recent years, the challenges related to water have reached a critical point. In Brazil, water plays a predominant role, being used mainly for irrigation of agricultural crops, public supply, industrial activities, energy generation, mineral extraction, aquaculture, navigation, tourism and leisure. Each purpose is intrinsically linked and can influence specific conditions related to the quantity and quality of water, as highlighted by the National Water Agency (ANA) [3].

The municipality of Ponta Grossa, located in the state of Paraná, has around 40% of its water supply coming from an artificial dam that was constructed in 1940, formed over the Pitangui River and the São Jorge River. The dam area extends over the municipalities of Castro and Carambeí and is located 20 km from the city center. The area allows people to contemplate nature and has become a place of leisure for the community [4].

Given the importance of the reservoir, it has become a priority for research into water, fish and sediment quality. Research carried out over the last 10 years by the Environmental and Sanitary Analytical Chemistry group at the State University of Ponta Grossa (QAAS-UEPG) has shown that the water, fish and sediments contain concentrations of heavy metals and organochlorine pesticides from the different agricultural crops grown around the reservoir. The research reveals concerns about the quality of the water made available to the population of the city of Ponta Grossa and the riverside population, as well as to consumers of fish from the reservoir [5,6].

Research like this brings the university closer to the community, as science is being applied to a reality close to the individual, generating an opportunity to debate science and Environmental Education (EE), given that one of the great challenges of teaching today, at all different levels, is to articulate, in a meaningful way, what is taught with situations that are relevant to the student's life in society.

In this context, we point out that the development of concepts related to chemistry and EE in the classroom can offer teachers an opportunity to work in an interdisciplinary way, since contextualized chemistry teaching is a possibility to break with the learning based on the transmission of knowledge where the teacher is the holder of knowledge. The teaching that is contextualized to the student's reality is capable of working critically with science and contributing to the formation of critical citizens.

In teaching chemistry (TC) it is important to include

themes that are close to the student's reality, providing meaningful learning, aimed at forming a critical citizen, aware of their role in society, thus resulting in more consistent learning, creating an environment where the student can articulate and construct their own learning [7].

Over the last 50 years, environmental education has been debated at all levels of society. Many conferences have been held in different countries, such as Tbilisi, Rio 92 and Rio+20, among others. At these meetings, documents were drawn up so that countries would commit to reducing actions that harm the environment. These documents were drawn up using various guidelines from researchers on the condition of the planet [8]. We are currently living through the 2030 Agenda on the seventeen goals for sustainable development. This new document highlights the need to link social and educational issues with local environmental problems, with the goal of creating a planet that allows humanity to survive.

Thus, articulating scientific concepts by problematizing local environmental issues seems to be one of the best strategies for carrying out EE education in schools. This is a scientific research strategy that aims to analyze a phenomenon and/or, as in this work, analyze a case of current environmental contamination within its real context. The aim of this study is to generate knowledge about an environmental phenomenon by identifying the research problem, collecting data, analyzing the context and finally finding solutions to the problem identified, as well as being able to develop critical analysis in society about the problem discussed.

Several authors have worked with EE in the TC. Coelho and Santos [9, 10] pointed out that there are various ways of linking TC to environmental education, whether through playfulness, films, documentaries, debates on contemporary issues, among other possibilities. Oliveira [11] in their work showed a way of linking pH and TC with environmental education through the reality of the students and the topic of atmospheric pollution. Júnior, Sá and Campos [12] linked agroecology, TC and EE. The authors report that this relationship allowed students to better understand the chemistry content and socio-environmental issues. Souza, Silva and Costa [13], in turn, linked CT with sustainability in an interdisciplinary way using the principles of Green Chemistry to teach various contents.

The use of the 3 pedagogical moments (3PM) proposed by Delizoicov and Angotti [14] can facilitate this link between TC and EE and result in a didactic experience that could be replicated in different situations. The use of the 3PM initially involves the Initial Problematization (IP) stage, in which students are motivated to express their ideas on a proposed topic or question, enabling them to survey their preconceptions about what will be developed during the following stages. The second stage is the Knowledge Organization (KO), which will bring out the scientific aspects through the study of concepts related to the proposed topic. The last stage is the Knowledge application (KA), where all the knowledge acquired by the students is used to reframe the initial problem with a new critical analysis. In order to develop this didactic sequence, various activities should be used to seek a broader interpretation of all the knowledge so that students are able to apply the knowledge they have acquired in their daily lives, rather than simply finding a solution to a problem.

Angeli [15] presents a pedagogical intervention for the content of organic chemistry, relating the theme of plastics from an environmental perspective, adopting the Science-Technology-Society-Environment (STCE) approach supported by the 3PM methodology. The author reports good results, in addition to technical knowledge, such as, the development of students critical thinking about the social, environmental and technological issues involved from the production of plastics to the disposal of these plastic materials.

Borges, Lodi and Ribeiro [16] used the 3PM in a workshop on drugs in chemistry class. The IP was carried out through an initial debate. In the KO, theoretical lessons were developed on illicit drugs, including their history, classification and concepts of organic chemistry, relating them to the active ingredients of drugs. And in the KA, the students applied what they had learned by making posters, which put them at the center of the learning process.

In this way, we present a proposal for a didactic sequence using the 3PM to teach chemical concepts, with a local contamination problem as the topic of discussion. In order to actively contribute to the training of agricultural technicians, a project was carried out through a workshop on the theme "Contamination by pesticides and heavy metals in the Alagados Dam in Ponta Grossa- PR".

2. Material and Methods

The environmental pedagogical workshop was carried out involving second and third year students from the Integrated Agricultural Technical Course at a state public school in the city of Ponta Grossa, Paraná.

The work was developed following Delizoicov and Muenchen's 3MP [17], relating the themes of pesticides and heavy metals to environmental contamination in the Alagados Reservoir.

2.1 First Pedagogical Moment: Initial problematization (IP)

Before starting the IP stage, a questionnaire was administered to the participants. The questionnaire was planned and created to assess the students' prior knowledge of pesticides and heavy metals, since in the first IP the teacher's role is not to give scientific answers and explanations, but to provide discussion among the students, to sow doubts and questions about this topic in order to strengthen the discussion raised, as well as to identify possible gaps in the student's understanding and their limitations in knowledge about them [14 - 18].

The questionnaire consisted of discursive and multiple-choice questions designed to explore the ideas, opinions and knowledge of the participants. The PLICKLERS tool was used for this purpose. The PLICKLERS tool is an application that enables multiple-choice questionnaires and polls to be administered to a group of people, who respond via a QR-CODE (Fig. 1), which is made available on the site itself, once it has been printed and distributed to the participants. Data is collected by scanning this QR-CODE with the smartphone camera, since each end of the QR-CODE is equivalent to an alternative (a, b, c or d).

In order to promote a debate among the participants, the IP was carried out through the presentation of reports shown on the local television network with the greatest reach on the research by Stremel [5] and Voigt [6]. The reports address the environmental contamination of fish by pesticides and heavy metals in the water reservoir, as well as the consequences for the environment and the community. Faced with the IP presented, the participants began a debate on the responsibility of the institutions involved in environmental contamination.

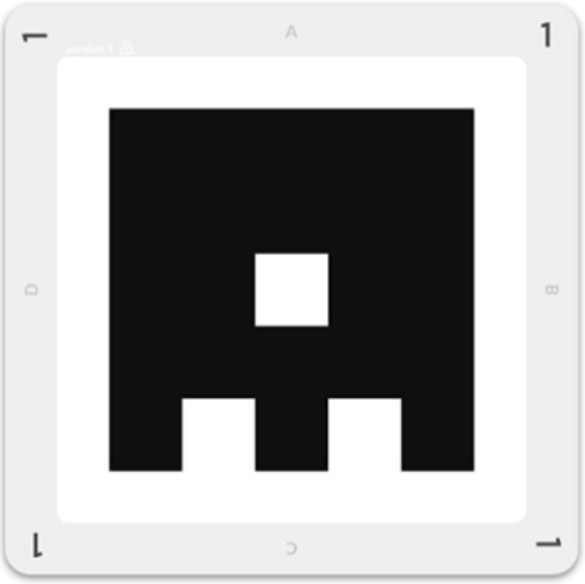

Fig. 1. QR-CODE model used in the PLICKERS application.

2.2 Second Pedagogical Moment:Knowledge Organization (KO)

The KO used presentations on the subject of pesticides:

- Agriculture in Brazil and in the world;
- Population growth and the need to produce food on a large scale;
- Use and classification of pesticides and their toxicity;
- Organic functions and structures that make up pesticides;
- Dispersion and persistence of pesticides in the environment.

For the topic involving metals, the following subjects were worked on:

- Definition of heavy metals and their chemical properties;
- Heavy metals essential for health;
- Properties and uses of heavy metals;
- Heavy metal poisoning and health risks;
- Dynamics of heavy metals in the environment, bioaccumulation and biomagnification.

The KO also gave a presentation on the Alagados Dam, its history, location and importance.

2.3 Third Pedagogical moment: Knowledge Application (KA)

At the end of the workshop, the third pedagogical momentis marked by the application of the KA acquired. At this point, the students had already had access to the information from the newspaper report, discussed the issue of dam contamination and learned about the chemistry content. The questionnaire was retaken with the PLICKERS tool to monitor their knowledge of the chemical concepts. As a final production, to synthesize the knowledge acquired in the workshop, the students were asked to create an e-mail, taking into account the environmental problem discussed. The students wrote short texts with questions or notes that they felt were important, addressing them for the institutions responsible for the water reservoir to answer. Finally, the texts were summarized in an e-mail and sent to the State Sanitation Company that uses the water, the Municipal Environment Department, the Electricity Company that manages the reservoir, the Municipal Environment Council and the State Environmental Institute.

3. Results and Discussion

3.1 Students' preconceptions

At first, a questionnaire was administered using the PLICKERS tool, with the aim of obtaining the students' preconceptions about pesticides and heavy metals. As an example, some questions and answers were selected for analysis and are presented below:

Regarding pesticides, what is your position on the use of these substances?

The students showed they were aware of the risks of its use, but also that they agreed with its use. Examples of these ideas include:

Student A - *"The pesticides are necessary for good production and even faster in the case of large producers, but not in excess and with due care"*

Student B - "*Whether we like it or not, it's bad for us humans, but it's a more practical solution for producers"*

Student C - "*These are dangerous products, but it's the only way out for producers, it's faster and more efficient"*

Student D - "*I think it's important to use it consciously"*

Student E - "*When not used correctly, it can cause serious damage to the environment, but if you don't use it, it ends up damaging crop production, so I think you should use it."*

In the multiple choice question:

What is the correct definition of pesticides?

71% of the participants marked the correct alternative: *"Synthetic chemical products used to eliminate an unwanted target, with the justification of controlling diseases caused by these vectors and regulating the growth of vegetation"*, 29% selected the alternative: "*Chemical substances used to increase the production of the desired crop*" and the alternatives "*Poison used only for pest control*" and "*Pesticides used in agriculture to increase the degree of fertility in the soil"* were not cited.

The responses show that the students already have a good knowledge of pesticides and are aware of their risks. This is justified by the fact that these students are part of a technical course in agriculture, which has a lot of content related to this subject. Recent research has shown that due to the great repercussions that the subject of pesticides has gained in the media, especially in relation to its risks, the population has increased its curiosity and concern, which leads to a greater perception of the importance of this subject [19]. However, much of this information is associated with fake news, showing how much the topic of pesticides should be worked on in the classroom using references that follow scientific rigor, such as articles or theses that have been evaluated and published [20].

In the question: *What is the best definition of heavy metals?*

48% of the participants answered the correct alternative "*A group of chemical elements with high density and toxicity in low doses*", 28% marked the alternative "A group of chemical elements with high added value and high density", 17% think it

is "*Metals with higher density*", and another 7% "*Metals harmful for health*".

In the question, *"What is the problem with the accumulation of metals in the environment?*

61% of the participants selected the alternative "*These have low degradability, high bioaccumulation power and toxicity for living organisms*", 25% of the participants thought it was "*The death of various living beings and modification in the organism of others*", 7% "*It alters the pH of the water making it unfit for consumption*" and another 7% "*Contamination of soil, water and fish"*.

The answers given show that less than half of the students had scientific knowledge about heavy metals. In relation to the risks of these substances in the environment, there was a higher percentage of correct answers, probably due to the fact that the students have subjects available on the course curriculum that include waste and its dangers. Thus, with these previous conceptions of the students, it was possible to propose a didactic sequence based on the 3 PM involving chemistry content and its relationship with a local environmental problem, with the aim of re-signifying this knowledge for the students.

3.2 Second Pedagogical Moment: Knowledge Organization (KO)

In the IP, the reports (Fig. 2) from the research carried out in the flooded reservoir related to the contamination of fish by pesticides and heavy metals were shown.

Fig. 2. Illustrative photos of the reports shown.

After viewing the reports, a debate was held on the students' knowledge of the reservoir and whether they were aware of its use for the city's water supply. At this point, it was possible to see that the students were not aware of the importance of this reservoir for the city, much less its contamination. These observations allow us to state that this first pedagogical moment IP is a fundamental stage for the configuration of all the following stages. Delizoicov and Angotti, [14] recommend that the teacher's stance at this point should be more towards "*questioning and raising doubts about the subject rather than answering and providing explanations*". They also explain that the criterion for choosing questions "*is their link to the content to be developed"*. Thus, at this point it was possible to make the students realize the need to acquire new knowledge in relation to pesticides and heavy metals, because they recognize the fragility of their arguments. Furthermore, this stage was important for shaping the problem addressed in relation to the contamination of fish in the reservoir, so that new knowledge could be learned. It is important that such problems link scientific knowledge with other knowledge when interpreting situations, in order to recognize that science is important for understanding the situations that are being problematized [21].

To develop the KO stage, chemistry content was selected that would help students understand the properties that could lead pesticides and heavy metals to have toxic characteristics. To this end, slides were used during the lessons that included content on organic functions, using as a reference the so-called "dirty dozen" organochlorine pesticides that are part of the Stockholm Convention on their worldwide ban. Figure 3 shows the image we worked on in class, which illustrates the chemical formulas of organochlorines banned in Brazil.

Using figure 3, it was possible to work out the different organic functions that are present in the structures of each of these pesticides, their nomenclature, the types of saturated and unsaturated bonds and their toxic properties. It was possible to analyze the structures of organochlorines and identify the similarity between them, the presence of chlorine, and thus explain the toxicity of chlorine, its harm to the environment and consequently to health and highlight the need for the Agricultural Technician to know the chemical formulas of the products they intend to use and assess whether they have any toxicity to the environment.

The heavy metals presented as examples (Mercury, Chromium, Cadmium, Lead and Arsenic) are elements known to the students, but the difference is classifying them as heavy metals and after presenting where each of the examples has been or is used in everyday life, the risks to human and environmental health that an excess of them can cause were presented.

3.3 Third Pedagogical moment: Knowledge Application (KA)

In the KA, where the initial problem is linked to the concepts presented, the aim was to understand the problem of contamination of the Alagados Dam and how this imbalance affects the environment and society.

At this point in the workshop, there was an integrative reconciliation involving the knowledge presented and developed in relation to the quality of the water distributed to the municipality. The report was shown again and the students were encouraged to pay attention to what the bodies

responsible for managing the reservoir were saying about the measures being taken. They were able to discuss, for example, the problem of contamination of fish by heavy metals and the difficulty of eliminating these substances due to bioaccumulation. They reflected on the challenge of controlling and banning the main sources of pesticide and heavy metal contamination in the Alagados Dam region. Through reflection and a critical eye, the students were encouraged to exercise their right as citizens, demanding from the local institutions in charge what they felt was necessary or considered to be the solution to this problem. Thus, each student proposed at least two questions to send to the institutions. The questions were compiled, analyzed and an e-mail was sent to the various institutions. Examples of some questions proposed by the students are shown in Figure 4.

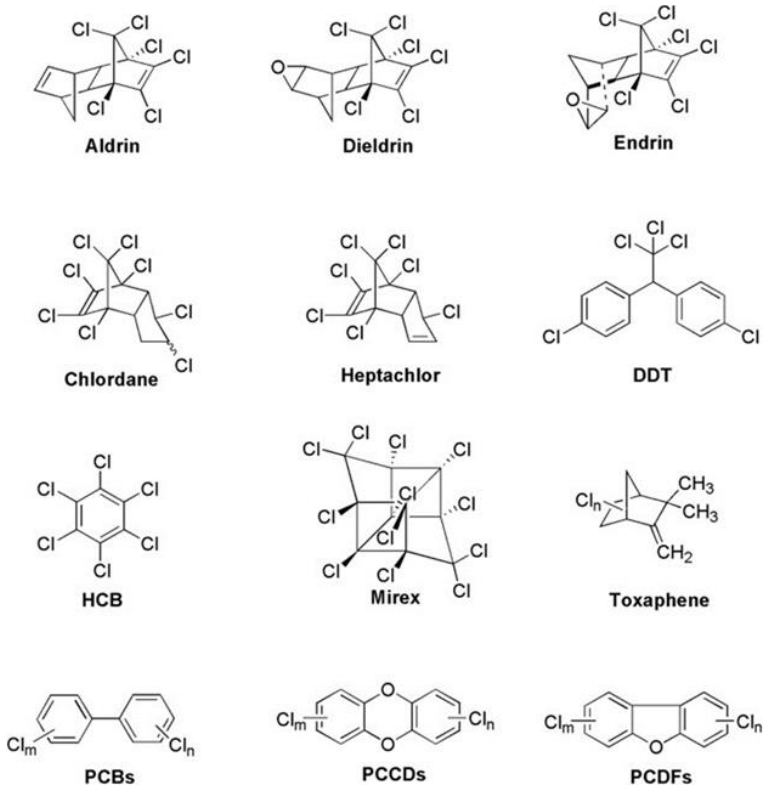

Fig. 3. "Dirty dozen".

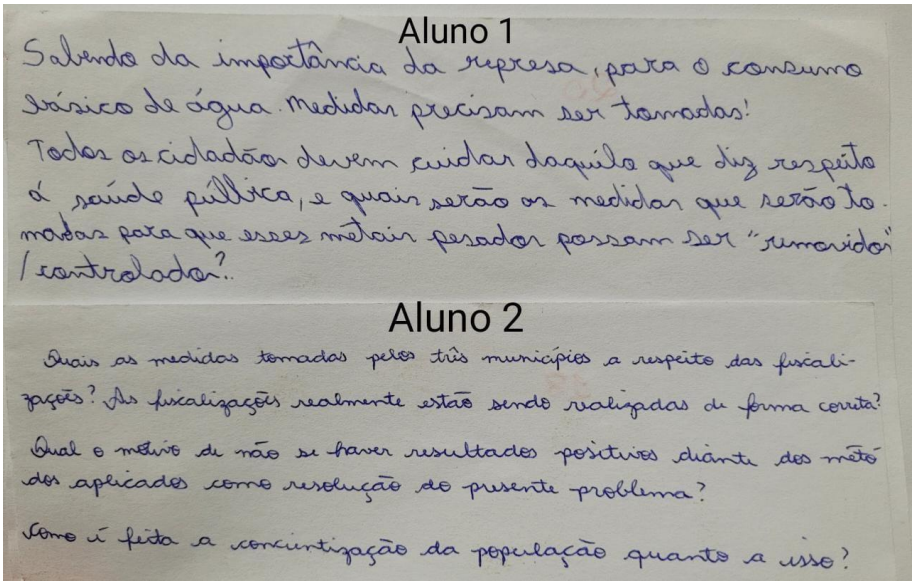

Fig. 4. Example of questions made up by the students.

After sending the email, only one body responded to the questions, and the answer was: "*Community awareness-raising is carried out through door-to-door guidance on the correct destination of waste and regularization of sewage connections, as well as teacher training and activities with students on urban streams and watersheds. As for the Alagado reservoir, which is part of the Pitangui River, guidance was given to the surrounding community and the technical monitoring was left to the municipal environment department* ". No response was received from the other institucions.

This lack of interest on the part of the institucions responsible in answering the students' questions shows a sad reality in our country. The lack of commitment on the part of these institucions to serve the population, even though this is their greatest obligation and the reason they were created.

3.4 Contributions of the workshop to the technician's training

The content covered in the workshop is in line with the Paraná State Integrated Agricultural Technician Course Plan document, contributing to the training of professionals. Among the axes that the course covers, in terms of methodology, the course must work with problematization that reflects the reality in which these technicians will be inserted:

> "It is a question of using the problematization methodology, in the sense of challenging students to reflect on the reality that surrounds them with a view to seeking creative and original solutions to the problems that arise with regard to this reality: a) Elaborating questions about phenomena, facts and situations. b) Answering the questions elaborated in the light of theories and concepts already formulated about the object(s) studied - teaching content" [2].

The problematization of phenomena and the explanation of theories and concepts were practices that were present during the application of the workshop, which with the didactic sequence of the 3PM, proved to be a valid, interesting and compatible proposal with the objectives proposed for the didactic intervention in the form of an extracurricular workshop. Muchen [22] pointed out that classroom practice has a dynamic relationship with the organization of the curriculum, so that the 3MP can guide the construction of new proposals, as well as their implementation in the classroom. These moments, by incorporating Paulo Freire's concepts of dialogue and problematization [23], can enhance the teaching/learning process, contribute to the development of critical thinking and overcome problems, if dialogued from the student's reality [24].

It is therefore believed that the project has enabled these students to gain a greater understanding of a problem that can be generated by their actions. It should be remembered that the city of Ponta Grossa is one of the country's largest grain producers. Its main economic activity is agribusiness. Most of these technicians are absorbed by the local market and will work on the front line, using pesticides and fertilizers (a source of heavy metal contamination). For that reason, if these technicians are aware of the risks of misusing these products and the possible consequences, it could increase their care and responsibility for correct and conscious use.

4. Conclusions

The didactic sequence chosen to problematize the contamination of fish by pesticides and heavy metals in a water supply reservoir using the three pedagogical moments proved to be a very valid strategy for working with students on the Agricultural Technical Course. It made it possible to learn concepts involving metals and organic chemistry that were more compatible with the objectives proposed in the course plan and collaborated with the training of future professionals in relation to social and environmental aspects. The didactic experience linking TC and EE with the themes of pesticides and heavy metals resulted in the preparation of an e-mail sent to the responsible bodies, promoting critical thinking and decision-making in the students, which aroused greater interest in chemistry and its importance in understanding environmental and social problems.

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UEPG e CAAR.

Author Contributions

Milene Fernanda Bornat Machado: Research, writing - original draft, writing - revision and editing and data curation; Sandro Xavier de Campos: Supervision, formal analysis and methodology; Elias da Costa: Supervision and conceptualization.

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