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Socio-environmental themes in the training of Science teachers – a study involving the generation of plastic waste[1]

Víviam Cristina Costa Silva Santos[2]
Elaine Angelina Colagrande[3]

ABSTRACT

This article discusses the results of a qualitative study conducted with undergraduate students, with the aim of investigating their understanding of chemical, social, and environmental aspects involving the generation and disposal of solid waste, specifically plastic materials. The theoretical framework used was knowledge from the field of Environmental Education from a critical perspective. The study was conducted in the Chemistry undergraduate course at a federal university in Minas Gerais, as part of an environmentally oriented elective course, with the participation of six undergraduate students. Data collection was carried out in several stages, throughout a didactic sequence, involving questionnaires, case studies, and experimental activities. The data suggest that the undergraduate students developed a general understanding of the aspects addressed, showing a predominance of social and environmental aspects involving the socio-environmental theme addressed. The data highlighted the importance of developing activities with socio-environmental themes in initial teacher training.

KEYWORDS: Critical environmental education; Teacher training; Solid waste; Three pedagogical moments; Science teaching.

[1] Englisn version by Fabielle Rocha Cruz. *E-mail*: fabielle.cruz@gmail.com.

[2] Master's in Chemistry. Universidade Federal de Alfenas - UNIFAL, Alfenas, MG, Brasil. Orcid: https://orcid.org/0009-0007-7069-5281. *E-mail*: viviam.santos@sou.unifal-mg.edu.br.
[3] Doctor in Science. Universidade Federal de Alfenas – UNIFAL, Alfenas, MG, Brasil. Orcid: https://orcid.org/0000-0003-3307-3524. *E-mail*: elaine.colagrande@unifal-mg.edu.br.

Temáticas socioambientais na formação de professores de Ciências: um estudo envolvendo a geração de resíduos de materiais plásticos

RESUMO

O presente artigo discute resultados de uma pesquisa qualitativa desenvolvida com estudantes de licenciatura, com o objetivo de investigar suas compreensões sobre aspectos químicos, sociais e ambientais que envolvem a geração e destinação de resíduos sólidos, especificamente os materiais plásticos. Utilizaram-se como referencial teórico os conhecimentos do campo da Educação Ambiental em perspectiva crítica. A pesquisa ocorreu no curso de Química – Licenciatura de uma universidade federal mineira, no âmbito de uma disciplina optativa ambientalmente orientada, com a participação de seis licenciandos. A coleta de dados foi realizada em várias etapas, ao longo de uma sequência didática, envolvendo questionários, estudo de caso e atividade experimental. Os dados sugerem que os licenciandos desenvolveram compreensão geral dos aspectos tratados, mostrando predominância dos aspectos sociais e ambientais que envolvem a temática socioambiental abordada. Os dados evidenciaram a importância do desenvolvimento de atividades com temáticas socioambientais na formação inicial de professores.

PALAVRAS-CHAVE: Educação ambiental crítica; Formação de professores; Resíduos sólidos; Três momentos pedagógicos; Ensino de Ciências**.**

Temas socioambientales en la formación de profesores de Ciencias: un estudio sobre la generación de residuos plásticos

RESUMEN

Este artículo analiza los resultados de un estudio cualitativo realizado con estudiantes universitarios, con el objetivo de investigar su comprensión de los aspectos químicos, sociales y ambientales que involucran la generación y disposición de residuos sólidos, específicamente materiales plásticos. Se utilizó como marco teórico el conocimiento del campo de la Educación Ambiental desde una perspectiva crítica. La investigación se realizó en el curso de Licenciatura en Química de una universidad federal de Minas Gerais, en el ámbito de una asignatura optativa de orientación

ambiental, con la participación de seis estudiantes de grado. La recolección de datos se realizó en varias etapas, a lo largo de una secuencia didáctica, involucrando cuestionarios, estudios de casos y actividades experimentales. Los datos sugieren que los estudiantes universitarios desarrollaron una comprensión general de los aspectos abordados, mostrando predominio de los aspectos sociales y ambientales que involucran la temática socioambiental abordada. Los datos resaltaron la importancia de desarrollar actividades con temáticas socioambientales en la formación inicial docente.

PALABRAS CLAVE: Educación ambiental crítica; Formación docente; Residuos sólidos; Tres momentos pedagógicos; Enseñanza de las Ciências;

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Introduction

Due to their enormous popularity and rapid production, much of the plastic is produced and discarded after its first use, generating an excessive amount of waste, which is one of the factors that contribute to ecosystem imbalances (Carneiro *et al.*, 2021). The irregular disposal of plastic materials, according to Carneiro *et al.* (2021), is a problem generated both by consumers and other sectors of society, as well as by flaws in legislation, which make disposal in nature cheaper than effective management until the end of these materials' life cycle.

Souza *et al.* (2022) emphasize that the decomposition of plastic materials in nature is a concern due to their high durability and resistance to corrosion. Still on the subject of plastic waste, Amaral (2022) points out that we can take two actions to address this situation and minimize the impact of these products: investing in public policies or in Environmental Education so that the population rethinks their daily actions and understands that there is a shared responsibility. In this context of contemporary socio-environmental issues, such as the generation of plastic waste, teacher training and the promotion of

Environmental Education in schools emerge as fundamental actions to address these issues, aiming to raise awareness and also change attitudes and values through sustainable practices.

Regarding the field of science, this perspective is similar to the work of Arrigo *et al.* (2018), who emphasize that Chemistry Education focused on Environmental Education enables the discussion and problematization of environmental issues, seeking to develop critical citizens who strive for quality of life by acting responsibly. The work of Santos and Schnetzler (1996) also corroborates this point, highlighting that the discussion of social issues linked to Chemistry Education plays a fundamental role in developing citizens with basic skills, enabling them to make decisions regarding socio-environmental problems. Based on these initial reflections, this article, part of a master's research, aims to present the results of an investigation into undergraduate students' understanding of chemical, environmental, and social aspects involved in the issue of plastic waste generation, in the context of an optional course offered in a Chemistry undergraduate course.

To better understand this objective, concepts related to specific chemical content were adopted as chemical aspects, such as the understanding of polymer structures, chemical pollutants generated by the burning of plastics, and other aspects of this field of knowledge. Environmental aspects included the impacts of the presence of plastic materials on the natural environment. Social aspects included those focused on the quality of life, inclusion, and working conditions of recyclable material collectors, as well as social responsibility.

To discuss this topic and investigate the undergraduate students' understanding, a Teaching Sequence (TS) was developed using the Three Pedagogical Moments (3PM) as a methodological framework.

Environmental Education and Teacher Training

Given contemporary socio-environmental issues, including climate change and the generation and disposal of solid waste, it is essential that the education sector, in its human and professional development spaces, promote debates aimed at integrating Environmental Education, fostering critical thinking and decision-making on aspects related to the topic. Teacher training is a key area in this context.

Various studies have addressed the topic of Environmental Education and teacher training. Gouvêa (2006, p. 165), for example, reports that Environmental Education, for a time, presented a preservationist aspect, being reduced to practices "related to commemorative dates, the development of specific mini-projects, the care of vegetable gardens and gardens, the cultivation of medicinal plants, and the recycling of waste and materials." The same author also emphasizes that such practices are not effective in changing social lifestyles or reducing consumerism, as they do not raise the awareness that could promote changes in habits and attitudes. To facilitate these changes, Environmental Education should embrace the importance of citizenship, ethics, and justice. Therefore, it is necessary to reshape the social role of schools to promote an education focused on developing citizens who are more aware of socio-environmental problems, often caused by our lifestyles (Nascimento *et al.*, 2021). Furthermore, according to Nascimento *et al.* (2021), environmental educators can help develop ethical, reflective, and critical learners of an ecologically sustainable environment, developing the human skills of thinking, feeling, doing, resisting, and coping.

Regarding Higher Education, the focus of this research, Tozoni-Reis and Campos (2014, p. 159) problematized initial teacher training, reflecting on the role of Environmental Education in Basic Education, and concluded that it should be included at this level of education.

> There is a need to reformulate teacher training with a view to overcoming practical rationality, investing in their leading role in the construction and implementation of a school curriculum that guarantees the treatment of environmental issues.[4]

In this sense, offering opportunities for debate on environmental issues in initial teacher training courses is essential for the development of environmental initiatives in Basic Education.

Also, regarding the discussion of environmental issues in Higher Education, Oliveira and Carvalho (2011) report that, in Brazil, for formal Higher Education, it is possible to observe suggestions for inclusion in some policies focused on environmental issues and also in education. They point out that "the problems and challenges that permeate the relationship between curriculum, higher education, and environmental events cannot be resolved by simply incorporating 'an environmental dimension' into professional training curricula" (Oliveira; Carvalho, 2011, p. 10). The perspective guiding this article understands that such challenges are related to "how" to develop this dimension throughout initial training, so that it is meaningful and promotes changes in future professional performance. Martins and Schnetzler (2018) analyzed a continuing education program for teachers in Environmental Education taught from a critical perspective and centered on Collaborative Action Research. The authors point out that some studies show that Environmental Education is approached conservatively, when its participants embrace the interests of market capital and preserve the values and principles defended by ideologically dominant social groups.

In this sense, developing practices and activities within initial teacher training that address contemporary environmental issues critically and reflectively, such as the teaching sequence presented in this article, can foster the development of a broader perspective on these

[4] Translated from the original in Portuguese.

issues among this audience. This will be reflected in their future professional environments, the K-12 schools.

Some trends in Environmental Education

In this field of knowledge, some authors have noted differences between the educational practices developed, and these differences vary according to each individual's perceptions. Due to this plurality, the varied existing perceptions, and the possibility of choosing the one that will inspire our own practice, it becomes relevant to understand the different understandings of Environmental Education.

Sauvé's (2005) study, for example, presents the notion of "current," which, according to the author, refers to a general way of conceiving and practicing Environmental Education. In her study, she identified 15 currents of Environmental Education, some traditionally older, such as the naturalist, conservationist/resource-oriented, resolutive, systemic, scientific, humanist, and moral/ethical currents, and others more recent, such as the holistic, bioregional, praxic, critical, feminist, ethnographic, and eco-education and sustainability currents. Furthermore, according to Sauvé (2005), a single current can incorporate a plurality and diversity of propositions; on the other hand, a single proposition can correspond to two or three different currents, depending on the angle from which it is analyzed, in which certain currents may share common characteristics.

Given the various existing currents, which can be found in works such as those by Sauvé (2005) and Carvalho (2004), among others, Layrargues and Lima (2014) conducted a mapping exercise, observing their main characteristics, a process that resulted in the proposal of what they termed "political-pedagogical macrotrends of EE": Conservationist, Pragmatic, and Critical.

According to these authors, the Conservationist trend takes into account ecological principles, valuing the affective aspects of caring for and preserving nature, and changing individual behaviors. In this type of trend,

there is no discussion of the contemporary social system and its relationship to environmental problems.

In the Pragmatic trend, the environment is distant from human components, characterized as a set of natural resources available to humans but at risk of depletion. This leads to actions such as combating waste and reusing waste, which can then be re-entered into industrial processes, following current consumption patterns (Layrargues; Lima, 2014). This trend focuses on solving environmental problems without promoting reflection on their causes and impacts, thus failing to include the economic, cultural, and social contexts associated with such problems.

The Critical trend focuses on politically addressing inequalities and socio-environmental injustice (Layrargues; Lima, 2014). This trend is guided by the goal of promoting social transformation, debating development and societal models, and recognizing the complexity of contemporary environmental issues. According to Sauvé (2005), this Environmental Education trend emphasizes the analysis of the social dynamics underlying environmental realities and problems. It also emphasizes "the contextualization of the topics covered and the importance of a dialogue between knowledge (formal scientific, everyday...), where these knowledges must be confronted, addressing different discourses with a critical approach to clarify action" (Sauvé, 2005, p. 31).

Given this context, based on knowledge about the diversity of understandings of Environmental Education, and considering the need for an Environmental Education that involves critical thinking and comprehensive observation of socio-environmental issues present in society, this article adopted Critical Environmental Education as its focus and theoretical framework.

To meet the research objective, a teaching sequence was planned and implemented using instruments aimed at constructing a perspective on this trend in Environmental Education, based on the dynamics of the "Three Pedagogical Moments" (3PM), which will be detailed in the methodology section.

Methodology: the research context

The research was conducted in person as part of an environmentally oriented elective course called "Socio-Environmental Issues and Teaching." Carvalho, Amaro, and Frankenberg (2012, p. 138) indicate in their study that an environmentally oriented course should include objectives and teaching program in its syllabus, "the intention of highlighting the socio-environmental dimension related to its specific content."

The course was offered by the Chemistry Undergraduate Program at a federal university in Minas Gerais in the first semester of 2022, with enrollment open to students from other undergraduate programs. The diversity sought through such openness can foster a more comprehensive education for undergraduate students, given that they will come from different fields of knowledge, enriching the discussions on the topics covered. This year, undergraduate students from the fields of Chemistry and Biological Sciences enrolled, and eight of them actively participated in the research.

The research adopted a qualitative approach that, according to Creswell (2010), is fundamentally interpretive. To deepen the undergraduate students' understanding of the different aspects, several instruments were used. According to Creswell (2010), these instruments are part of the qualitative procedures collected during the development of the teaching sequence. These were transcribed and interpreted, with subsequent presentation of inferences based on the data obtained. The research was approved by the university's Research Ethics Committee under opinion CAAE 57002022.6.0000.5142.

The data collection stage of the research occurred during the implementation of a teaching sequence based on the thematic approach of the three pedagogical moments (3PM), proposed by Demétrio Delizoicov, José André Angotti, and Marta Maria Pernambuco, through Freire's (1987)

dialogic-problematizing approach. This approach was planned and developed as one of the course activities.

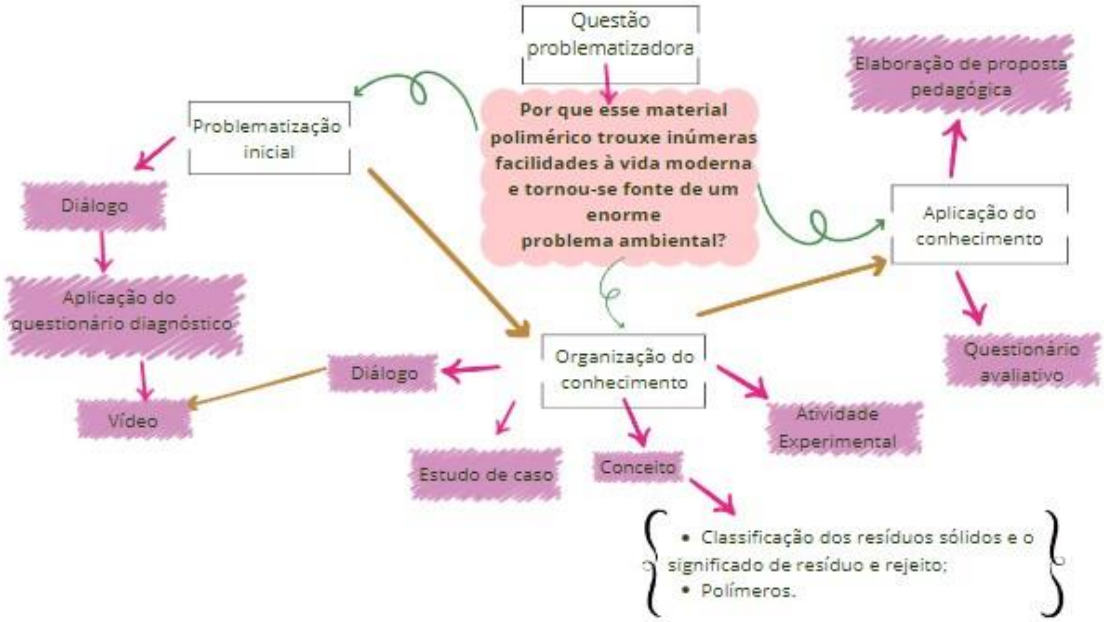
These authors propose, for the development of the classroom teaching program, as the name suggests, three pedagogical moments: in the first moment, called “initial problematization”, the teacher presents real situations that students experience, introducing scientific knowledge, questioning and problematizing knowledge, through discussions on the subject; in the “organization of knowledge”, the second pedagogical moment, students study knowledge through problem-solving and activities proposed in books, handouts and educational websites, materials necessary for understanding the themes and initial problematization, building knowledge; In the “application of knowledge,” the third pedagogical moment, students are expected to incorporate the acquired knowledge, and they are expected to use it to connect scientific concepts with real-life situations (Delizoicov; Angotti; Pernambuco, 2011, pp. 200-202).

In this sense, the 3PM was considered a potential and appropriate didactic organization for the research, contributing to a broad approach to the topic and involving elements of Critical Environmental Education, with the initial problematization, in this case, of the generation and disposal of plastic waste.

Research stages and data collection

The diagram in Figure 1 illustrates the organization of the planned teaching sequence and its stages. This diagram represents the three pedagogical moments and the data collection instruments used in each stage of the research:

Figure 1. Diagram of the TS organized in the approach of the 3PM – thematic generation of plastic materials.



Source: the authors, adapted from the study by Arrigo *et al.* (2018).

The first pedagogical moment was encouraged by the following question: "Why has this polymeric material (plastics) brought countless benefits to modern life and yet become the source of a huge environmental problem?" After the undergraduates answered this question in written form, a dialogue began between the researcher and the undergraduates, in which they could present their prior knowledge.

Subsequently, a diagnostic questionnaire was administered, with questions that addressed chemical, social, and environmental aspects of the topic, specifically plastic materials. At the end of this session, the link to the video entitled "History of Plastic" (available at: https://www.youtube.com/watch?v=_xRZA1wo68k) was provided, which addresses, among other things, the emergence of the material, its historical context, and the environmental impacts of its use and improper disposal. This video was then shared with the undergraduates after class, and could be viewed outside of class, and they could bring their questions to the next meeting. The knowledge organization stage began with a discussion about

the proposed extracurricular activity, aiming to determine whether they recognized the potential environmental and social impacts generated by the improper disposal of solid waste. A case study was then conducted, seeking to address social and environmental issues. Following this activity, a lecture-based discussion was held to explain and discuss the topic. In the following class, an experiment called "burning plastics" (adapted from https://www.youtube.com/watch?v=iqmOXwgjzOA) was conducted to determine whether the undergraduate students recognized the environmental impacts generated by the burning of these materials.

In the third and final pedagogical moment, knowledge application, the undergraduate students were asked to form pairs to share ideas and develop an extracurricular pedagogical proposal on the topic of plastics, involving Environmental Education and Chemistry/Science teaching, to be submitted on a date scheduled by the instructor responsible for the course. Pre-established criteria were used to develop this activity. After the proposal was explained, the undergraduate students completed an individual evaluation questionnaire with questions about the entire process in which they participated. It is worth noting that, for this article, the results of the pedagogical proposals were not presented.

The research data were processed using the Content Analysis technique, based on Laville and Dione (1999). According to the authors, in this technique, the researcher's main task is to systematize the content into elements that they will then organize into categories, constituting the so-called units of analysis.

The analysis was based on the definition adopted for chemical, environmental, and social aspects presented in the introduction to this article. The content of the selected messages was searched for elements that demonstrated the undergraduate students' understanding of these aspects. Throughout the process of selecting the units of analysis and subsequent categorization, categories emerged from the analyzed data. In the responses presented in the discussion, the units of analysis were highlighted.

Results and discussion

To analyze the understandings of the eight undergraduate students participating in the study regarding the topic addressed in the teaching sequence, the results are presented considering three aspects: 1) chemical, 2) social, and 3) environmental. For identification purposes throughout the discussion, participants were identified by codes L1 to L8, thus preserving anonymity.

1) Chemical Aspects

Because plastic materials are related to polymers, we considered it appropriate to explore the undergraduates' understanding of this relationship by asking the following question: "What do you understand by polymers?" The answers to this question were considered more consistent when they aligned with the suggestion of Da Cruz *et al.* (2020). This author reports that the word polymer comes from the Latin, where "*poly*" means many and "*mero*" means units, and that each mero or unit is a monomer that, through reactions, joins with another by bonds, forming polymers.

Therefore, the responses of five undergraduates demonstrated an understanding close to this chemical knowledge, as shown in the excerpt below: *"**They are large molecules,** formed by macromolecules, or grouped monomers"* (L6). Two undergraduates made a partial citation of chemical knowledge, when, for example, L7 indicated in his response: *"I understand that polymers are **small particles of plastic**"*. According to França *et al.* (2022, p. 277), "plastic is a type of polymer, called 'thermoplastic,' and all plastic is a polymer, but not all polymers are plastic." L4 indicated that they were unfamiliar with this term. When asked about the differences between regular and biodegradable plastic, seven undergraduates highlighted degradation time or lifespan, as can be seen in the following excerpts:

"Regular plastic pollutes and does not degrade. **Biodegradable plastic** is produced from materials that **degrade quickly**, so this type of plastic does not accumulate." (L4); *"Biodegradable plastic has an end,* ***a faster decomposition*** *than common plastic" (L6).*

Only one undergraduate student indicated degradation by biological agents: *"Biodegradable plastic has components that aid* ***degradation through biological agents****, for example, bacteria"* (L8).

According to França *et al.* (2022), biodegradation is the property of a material to be degraded by biological agents. Therefore, a polymer obtained from a renewable source is not always biodegradable. In terms of composition, common plastic is generally derived from petroleum, while biodegradable plastic is made from materials from renewable sources, such as cornstarch. Regarding decomposition, common plastic takes years to decompose in the environment, while biodegradable plastic degrades more quickly when exposed to natural conditions (humidity and bacteria) (França *et al.*, 2022).

During their TS, the undergraduate students also participated in a laboratory experiment based on the difference in pH (hydrogen ion potential) before and after burning plastic materials, to encourage reflection on potential environmental impacts. When waste is not collected properly, some people may choose to burn this material in their backyards or near their homes, which can lead to environmental damage (Rego *et al.*, 2014). The monomer that forms polyethylene (PE) is called ethylene, and the one that forms PVC is vinyl chloride. The combustion of PVC results in the release of a toxic gas—HCl (hydrochloric acid)—which irritates the eyes, nose, and throat when released at high levels (Da Fontoura, 2021).

In this experimental activity, the undergraduate students recorded the pH before the combustion reaction of PVC and PE samples (pH between 5 and 6) and after the combustion reaction, at which point they observed a decrease in pH values (below 5), which chemically characterizes an acidic environment. When asked about the pH

variation, most of the undergraduates responded that the pH decreased, which can cause environmental impacts. L6 also highlighted the toxicity of this combustion: *"**The gases released by burning plastics have acidic potential,** and PVC has significantly reduced pH, leading to the conclusion that it may **potentially have a greater polluting and toxic character.**".*

It must be acknowledged that the problem of burning plastic waste can also affect all biodiversity through inhalation. According to Guimarães and Silva (2020), the combustion of this material releases CO (carbon monoxide), CO_2 (carbon dioxide), and CH (hydrocarbons) into the atmosphere, which can impact the ozone layer and affect global warming, as well as air, soil, and water quality.

Still relating the burning of plastic materials to the environment, the undergraduates were asked about the toxicity of the gases released and the reaction of chlorine gas with water. All the undergraduates acknowledged and indicated that chlorine gas, in contact with water, produces hydrochloric acid, a toxic gas. Some sample responses are presented below:

*"Yes, **the gases are toxic**. Chlorine in contact with water produces HCl, which is a strong **acid** and likely the reason the pH of burning PVC is much lower than that of burning polyethylene." (L6).*

*"**CO, CO_2, and Cl_2 are toxic.** Chlorine gas in contact with water generates hydrochloric acid, which is also a toxic compound" (L4).*

Regarding chemical aspects, the data suggest that undergraduates had prior knowledge of the meaning of polymers and had little understanding of the differences between common and biodegradable plastics, indicating only that one type of plastic takes longer to degrade than the other. They also understood the toxicity of gases released into the environment when plastic waste is burned and that contact with water produces acids that are harmful to living beings.

2) Environmental Aspects

To discuss these aspects, data from the initial questionnaire, the case study, the experimental activity, and the final questionnaire were used. The first questionnaire asked undergraduates about their perceptions of the environmental consequences of discarding plastic packaging.

Analyzing their responses, it was clear that they understand and acknowledge the environmental impacts, particularly on the marine environment, and the problems caused by discarding this packaging on the streets, such as clogged drains, as demonstrated in the following excerpts:

*"**It generates several environmental impacts, especially in the marine environment, such as pollution in the seas.** However, in cities, the accumulation of plastic packaging on the streets can cause flooding during rainy seasons, as it clogs the drains" (L1).*

*"Pollution, **clogging of sewage channels and drains**, which can cause flooding, **danger to aquatic and terrestrial animals** due to contamination, asphyxiation, and accumulation of garbage" (L6).*

The responses emphasize the impacts on aquatic environments, including the marine environment. This result is similar to the study by Carneiro *et al*. (2021), in which the authors indicate the existence of several effects related to the low degradation and useful life of plastics, such as visual pollution due to improper disposal in city streets and parks, clogging of public roads, among others. In the marine environment, the same authors indicate that plastic waste can be carried for long kilometers at sea, affecting marine life. In this sense, Environmental Education plays an important role in raising awareness of socio-environmental issues, not only to solve current problems but also to reflect on ways to prevent preventable problems.

Another activity present throughout the teaching sequence and carried out in pairs (identified by D1 to D4) was a fictitious case study involving a hypothetical industry, due to its plastic production activities and

improper disposal, which triggered an investigation to assess environmental damage. Case study activities aim to develop skills such as problem-solving, hypothesizing, proposing solutions, and critical and reflective thinking (Pereira *et al.,* 2009).

This activity, with characteristics different from those of questionnaires, was used to determine whether undergraduates would recognize the environmental impacts of plastic use and suggest possible collectively agreed-upon action proposals—important characteristics for critical environmental education practices. The results indicated that all pairs were able to propose preventive actions, actions to be taken by both the industry and regulatory agencies. Some excerpts below illustrate this point:

*"**Regulation of the chemical industry**... analyzes the affected area and the chemical components, in addition to producing a storm drainage system...collection of liquid and gases produced" (D3).*

*"Firstly, a study of fauna and flora survey, and comparison of this study with those carried out before the implementation of the industry... **Conversation/investigation with the population living in the area, or close to it**, to gather information on health problems that appeared after oil exploration" (D4).*

In the solution stage proposed by the undergraduates, it was possible to observe, based on the highlighted units of analysis, that there are elements related to the responsibility of the industrial sector, as well as the necessary involvement of society in the search for solutions to socio-environmental issues. This fact suggests an initial approach to the principles of Environmental Education from a more critical perspective, as highlighted by Sauvé (2005) and Layrargues and Lima (2014).

The observation of an initial approach is justified by the fact that this case study activity occurred after the theoretical foundation and discussion on the plurality of Environmental Education, and it is inferred that this introductory part of the foundation may have

influenced the undergraduates' reflections. The results suggest that the activity fostered, in a way that differed from and complemented the initial questionnaire, the understanding of the undergraduates' perceptions regarding the environmental impacts generated by the irregular disposal of plastic waste. In the final questionnaire, one of the questions addressed the future consumption and solid waste disposal practices of the participating undergraduates, as these may influence their actions as future teachers. L1 focused his response in this latter direction; the other undergraduates focused on their actions as citizens. The results of the question also indicated the undergraduates' understanding of the importance of proper disposal, reuse, and recycling, and three undergraduates emphasized reducing the consumption of plastic materials in their responses:

*"**I intend to develop activities in the teaching of Science and Biology that cause the same impact** and the same concern that I had throughout the implementation of the didactic sequence, that is, to give meaning/sense to the students, in their studies." (L1).*

*"For some time now, **I've been trying to reduce my plastic consumption and reuse as much as possible**. I also separate organic waste from recyclables to ensure proper disposal of plastic." (L8).*

At the end of this topic, which addressed undergraduate students' perceptions of environmental issues, it appears that, in general, the undergraduates reflected on the impacts generated by the irregular disposal of plastic waste and highlighted concerns by stating that they intend to discuss the topic in their classes and, as citizens, take measures to reduce the potential impacts generated by plastic consumption. However, it also appears that, to develop a more critical perspective, not just a problem-solving one, students need more time and in-depth exploration of situations involving socio-environmental issues.

3) Social aspects

Regarding the discussion of social aspects, an important point related to the research theme was observing participants' understanding of the role of solid waste collectors, given that this is a current and ongoing socio-environmental issue. Raising awareness and encouraging entrepreneurial practices have been important actions for the inclusion of people who perform this activity, which is both social and economic.

The Ministry of the Environment reports that collectors of reusable and recyclable materials work in selective collection activities, playing a fundamental role in the implementation of the National Solid Waste Policy (PNRS). This work often takes place under unfavorable working conditions (on the streets and in landfills) and independently, or collectively (cooperatives and associations).

Recyclable material collectors play an important role in the recycling production chain, being at the forefront of the production process. However, they are the ones who earn the least, living in poverty, on the streets, and in landfills throughout Brazil (MNCR, 2023). The initial questionnaire asked undergraduates about their understanding of the role of waste pickers in society. The responses indicated that the undergraduates understand the importance of this activity performed by waste pickers. However, they emphasized the technical characteristics of their work, followed by social reflections, as can be seen in the following sample responses:

*"**Their role is to send urban solid waste to specialized centers** that will correctly dispose of these materials." (L1).*

*"They do very important work, which unfortunately is necessary for our society. **Despite the importance of this service, the living and working conditions of waste pickers are very precarious.**" (L4).*

According to Oliveira and Cunha (2019), socially recognizing waste pickers as professionals is important to strengthen their achievements and embrace challenges and opportunities within the profession. This social

aspect should be addressed in teacher training, fostering reflection and raising awareness about this socio-environmental issue that must go beyond the characteristics of the materials themselves. This social recognition of waste pickers is consistent with Critical Environmental Education, which, according to Layrargues and Lima (2014), seeks to politically address inequalities and socio-environmental injustice.

During the experimental activity, undergraduate students were also asked about their understanding of the socio-environmental impacts of burning plastic waste, considering, for example, that several respiratory diseases are linked to the exposure and absorption of air pollutants, such as asthma, bronchitis, emphysema, and lung cancer (Rego *et al.,* 2014). The results showed that the undergraduates understand that burning this waste releases toxic gases that are harmful to both the environment and human beings, as shown in the examples of responses described below:

"Yes. This type of practice can cause many negative impacts, ***both on human health when breathing these gases and on the environment, further exacerbating global warming****. In other words, the socio-environmental impact generated by this practice is significant." (L1).*

"Yes. The release of gases toxic to us humans and the environment—CO and CO_2*—****are gases that aggravate the greenhouse effect****, increasing solar radiation on plants and consequently increasing temperature. HCl is a highly toxic acid with a low pH that* ***can alter the pH of water and kill marine animals and plants."*** *(L6).*

These impressions are important because they suggest that students have comprehensively reflected on the socio-environmental impacts generated by the burning of plastic waste and, based on this, can plan future actions in schools that foster critical decision-making.

The results presented regarding the three aspects (chemical, environmental, and social) indicate the importance of discussing them in teacher training, considering that undergraduates need to reflect on and study socio-environmental issues before proposing actions in schools with their future students. This investigation corroborates Torales'

(2013, p. 9) argument, which emphasizes that teacher training, along with other elements that are part of the school environment, is an important part of incorporating environmental issues into the curriculum. Without "an understanding of environmental issues in their political, ideological, social, and economic aspects, seeking to build values and attitudes, these actions tend to lose their character as alternatives for the renewal of pedagogical practice."

In this sense, it is understood that the promotion of activities and practices that address environmental issues from a Critical Environmental Education perspective, as intended by the TS planned for the research presented in this article, can favor debate and the construction of knowledge collectively, helping to strengthen the theoretical basis of future teachers for the elaboration of new pedagogical actions that address these issues.

Conclusion

This article aimed to present the results of an investigation into the understanding of undergraduate students participating in the research on the chemical, environmental, and social aspects involved in the generation of plastic waste.

By analyzing the chemical aspects, the responses to the initial questionnaire suggest a necessary conceptual deepening of these undergraduate students on the subject, and the responses to the experimental activity suggest an understanding of the damage caused by the burning of plastic materials, a practice often used to dispose of this type of material.

Regarding the environmental aspects, through the activities proposed in the TS, the undergraduate students were able to reflect on situations that can occur in everyday society, as presented in the case study, and chemically observe the products of the burning of this type of material. The responses to the final questionnaire suggest an understanding of the undergraduate

students regarding their future responsibilities regarding the consumption and disposal of plastic materials, both as educators and citizens, but still reveal specific habits that deviate from Critical Environmental Education.

Regarding the social aspect, specifically regarding the role of recyclable material collectors, despite mentioning the technical nature of this type of activity, all undergraduates expressed concerns about the social problems faced by this category of workers. This discussion, in turn, approaches the field of Environmental Education from a more critical perspective.

It is hoped that the results presented and discussed in this article will provide elements for promoting initiatives aimed at initial and continuing teacher training that can foster reflection on the causes and consequences of socio-environmental issues. This will spark interest in deepening knowledge about Critical Environmental Education, which can assist teachers in developing initiatives that integrate environmental issues into school settings.

References

AMARAL, C. P. Ação antrópica, descaso, degradação ambiental e a ascensão do plástico/Anthropicaction, neglect, environmental degradation and the rise of plastic. *Brazilian Journal of Development*, [S. l.], v. 8, n. 4, p. 26640–26651, 2022.

ARRIGO, V. et al. O ensino de química e a educação ambiental: uma proposta para trabalhar conteúdos de pilhas e baterias. *Experiências em Ensino de Ciências*, v. 13, n. 5, 2018.

BRASIL. Ministério do Meio Ambiente. *Plano nacional de resíduos sólidos*. Brasília: Diário Oficial da União, 2012. 103 p.

CARNEIRO, T. M. Q. A.; DA SILVA, L. A.; GUENTHER, M. A poluição por plásticos e a Educação Ambiental como ferramenta de sensibilização. *Revista Brasileira de Educação Ambiental (RevBEA)*, v. 16, n. 6, 2021.

CARVALHO, I. C. M.; AMARO, I.; FRANKENBERG, C. L. C. (2012). Ambientalização Curricular e Pesquisas Ambientalmente Orientadas na PUCRS: um levantamento preliminar. In: LEME, P. C. S.; PAVESI, A.; ALBA, D.; GONZÁLEZ, M. J. D. (Coord.). *Visões e Experiências Ibero-Americanas de Sustentabilidade nas Universidades*. Granada/ ES: Gráficas Alhambra, p. 137-143, 2012.

CARVALHO, I. C. M. Educação ambiental crítica: nomes e endereçamentos da educação. *In*: LAYRARGUES, P. P. (coord.). *Identidades da educação ambiental brasileira*. Brasília: MMM, 2004. p. 13-24. Disponível em: https://cutt.ly/kxb9pGX.

CRESWELL, J. W. *Projeto de pesquisa: métodos qualitativo, quantitativo e misto.* Porto Alegre: Ed. ARTMED, 3ª edição, 2010, 296 p.

CRUZ, B. S. M. da; SOUZA, M. L. de; FREITAS, A. B. R. de. Reutilização de plásticos: uma forma de articular a Educação Ambiental e o ensino de polímeros através de uma feira de ciências. *Revista Eletrônica Perspectivas da Ciência e Tecnologia*, v. 12, 2020.

DA FONTOURA, M. Comportamento ao fogo dos polímeros halogenados (PVC, CPVC, PTFE). *Ignis: Revista Técnico Científica do Corpo de Bombeiros Militar de Santa Catarina*, v. 6, n. esp., p. 1-14, 2021.

DELIZOICOV, D.; ANGOTTI, J. A.; PERNAMBUCO, M. M. *Ensino de Ciências:* Fundamentos e Métodos. 4. ed. São Paulo: Cortez, 2011.

FRANÇA, D. et al. As faces do plástico: uma proposta de aula sobre sustentabilidade. *Química Nova na Escola*, v. 43, n. 3, p. 277-286, 2022.

FREIRE, P. *Pedagogia do Oprimido*. 17. ed. Rio de Janeiro: Paz e Terra, 1987.

GOUVÊA, G. R. R. Rumos da formação de professores para a Educação Ambiental. *Educar*, Curitiba, n. 27, p. 163-179, Editora UFPR, 2006.

GUIMARÃES, V. M. B.; SILVA, K. N. A. da. Impactos socioambientais do plástico descartável: estudo de caso nas redes de fastfood em Dourados/MS. *Revista on Line De Extensão E Cultura- RealizAção*, v. 7, n. 13, p. 97-120, 2020.

LAVILLE, C.; DIONNE, J. *A construção do Saber: Manual de metodologia de pesquisa em Ciências Humanas.* Porto Alegre: Artmed; Belo Horizonte (MG): Editora UFMG, 1999.

LAYRARGUES, P. P.; LIMA, G. F. DA C.. As macrotendências político-pedagógicas da educação ambiental brasileira. Ambiente & Sociedade, v. 17, n. 1, p. 23–40, jan. 2014.

MARTINS, J. P. A.; SCHNETZLER, R. P. Formação de professores em educação ambiental crítica centrada na investigação-ação e na parceria colaborativa. *Ciência & Educação,* Bauru, v. 24, n. 3, p. 581-598, 2018.

MINISTÉRIO DO MEIO AMBIENTE. Disponível em: https://antigo.mma.gov.br/cidades-sustentaveis/residuos-solidos/catadores-de-materiais-reciclaveis.html Acesso em: 10 jan. 2024.

MOVIMENTO NACIONAL DOS CATADORES DE MATERIAIS RECICLÁVEIS (MNCR). Disponível em: https://www.mncr.org.br/biblioteca/legislacao/classificacao-brasileira-deocupacoes-cbo Acesso em: 10 jan. 2024.

NASCIMENTO, L. M. B. et al. A emergência do educador ambiental crítico a partir da formação docente: importância do saber socioambiental na construção de projetos de intervenção coletivos. *Revista Brasileira de Educação Ambiental (RevBEA)*, [S. l.], v. 16, n. 2, p. 212–231, 2021.

OLIVEIRA, M. G.; CARVALHO, L. M. As três dimensões da educação ambiental – política, valorativa e dos conhecimentos - nos projetos político-pedagógicos de cursos de pedagogia de Universidades Federais Brasileiras. In: *VI Encontro "Pesquisa em Educação Ambiental"*: A Pesquisa em Educação Ambiental e a Pós-Graduação no Brasil. Ribeirão Preto, set. 2011.

OLIVEIRA, P. H. F.; CUNHA, A. G. M. O catador de resíduos sólidos e sua função como empreendedor social numa visão contemporânea. *Entrepreneurship*, v.3, n.1, p.26-31, 2019.

PEREIRA, L. DE T. K.; GODOY, D. M. A.; TERÇARIOL, D. Estudo de caso como procedimento de pesquisa científica: reflexão a partir da clínica fonoaudiológica. *Psicologia: Reflexão e Crítica*, v. 22, n. 3, p. 422–429, 2009.

REGO, F. A. H.; COÊLHO, J. F. R.; BARROS, V. L. L. Análise dos efeitos negativos causados pela queima do lixo doméstico em áreas urbanas de Caxias (MA). *Revista Humana Et Al*, v. 1, n. 1, p. 50 - 60, 2014.

SANTOS, W. L. P.; SCHNETZLER, R. P. Função social: o que significa ensino de química para formar o cidadão? *Química Nova na Escola*, v. 4, p. 28–34, 1996.

SAUVÉ, L. *Uma cartografia das correntes em educação ambiental*. In: Sato, M., Carvalho, I. (Orgs.). Educação Ambiental: pesquisa e desafios. Porto Alegre: Artmed. p. 17-44. 2005.

SOUZA et al. Plástico no mar: Polímeros à deriva! *Química Nova na Escola*. São Paulo-SP, v. 43, n. 3, p. 320-329, 2022.

TORALES, M. A. A inserção da educação ambiental nos currículos escolares e o papel dos professores: da ação escolar a ação educativo-comunitária como compromisso político-ideológico. *REMEA - Revista Eletrônica do Mestrado em Educação Ambiental*, [S. l.], p. 1–17, 2013. DOI: 10.14295/remea.v0i0.3437. Disponível em: https://periodicos.furg.br/remea/article/view/3437. Acesso em: 23 jun. 2024.

TOZONI-REIS, M. F. C; CAMPOS, L. M. L. Educação ambiental escolar, formação humana e formação de professores: articulações necessárias. *Educar em Revista*, Setor de Educação - Campus Rebouças – UFPR, 2014.

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