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ELECTRONIC WASTE: THE PROBLEM WITH THE ENVIRONMENT AND ITS ENVIRONMENTAL IMPACTS – WHAT DOES SCHOOL HAVE TO DO WITH IT?

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Abstract: The present study aimed to analyze how the topic of electronic waste is addressed in Basic Education, through a bibliographic survey conducted between 2016 and 2021. Solid waste (SW) has been an integral part of human life throughout history, and with technological advances and increased consumption, there has been a growing generation of electronic waste, whose inadequate management has serious socio-environmental impacts. In view of the above, the methodology adopted in this study was structured in three stages: integrative literature review, search and selection of articles, and interpretation and analysis of the data collected. The results indicate that, although there are a considerable number of publications on the subject, there is still a lack of studies that promote a critical and interdisciplinary approach, which is essential for the effective consolidation of Environmental Education in the school curriculum. In addition, there is a need for pedagogical actions that transcend theoretical teaching, incorporating practical activities and projects that involve the school community, aiming at the formation of conscious citizens committed to sustainability.
Keywords: Conscious Consumption. Electronic Waste. Basic Education. Ecological Degradation.

INTRO

Solid waste (SW) has been part of human daily life for a long time. In recent decades, however, it has become one of the main threats to humanity (Fraguas *et al*., 2020), putting future generations at risk. This problem is directly related to the rapid growth of urban areas, coupled with population growth and economic development, significantly increasing waste generation and making its management a challenge for developed and developing countries (Saif *et al.*, 2025). It is estimated that, if current practices continue, global was-

te generation will reach 46 billion tons by the year 2050 (Maalouf and Mavropoulos, 2023).

It is well known that this increase in the production of large volumes of waste is linked to excessive and unbridled consumption, which can have consequences for the planet. In this sense, it is not just a matter of stopping consumption, not least because consumption is important for the survival of living beings, but it is necessary to have discernment about the appropriate disposal of this waste in society. The key issue is to understand that consumerism itself is the problem and that the practice should not become compulsive, indiscriminate, or status-driven. Solid waste is generated from various daily activities, such as household, industrial, agricultural, commercial, and hospital activities, among others.

Electronic waste, also called e-waste or Waste Electrical and Electronic Equipment (WEEE), for example, is one of the fastest growing types of solid waste in the world. In 2022 alone, 62 million tons were generated, equivalent to 7.8 kg per inhabitant, and is expected to reach 82 million tons in 2030, an increase of 33% compared to 2022 (Baldé *et al.,* 2024). Given this, WEEE management is a major challenge for humanity, as this waste has an impact on human health and the environment, mainly due to the presence of toxic substances. In addition, many people consume this equipment without considering the future damage caused by the accumulation of these materials and their improper disposal, which has global implications.

In 2022, Brazil generated approximately 2.4 billion kilograms of WEEE, corresponding to an average of 11.4 kg per inhabitant, positioning itself as the largest generator of electronic waste in South America and the second largest in the American continent (Baldé *et al.*, 2024). In addition, it stands out as the only South American country significantly involved in the manufacture of electronic equipment, especially consumer goods such as televisions, smartphones, and household appliances.

According to Monteiro *et al.* (2025), the management of electronic waste disposal is one of the most pressing environmental challenges today. The authors analyzed the behavior of consumers in an upper-middle-class neighborhood in Recife, Pernambuco, regarding the purchase of electronic equipment and its disposal. They identified that the main obstacles to proper disposal are the lack of information about collection sites and difficult access to the services offered, despite the fact that most consumers are in favor of WEEE recycling.

Most electronic waste materials are recyclable or can be reused (Verma and Prakash, 2020), but according to Moreira *et al.* (2024), many people are unaware of this due to the lack of awareness programs and selective collection points for the proper disposal of e-waste. When disposed of in inappropriate locations, electronic waste releases toxic substances, causing serious problems for the environment and human health (Verma and Prakash, 2020, Bhardwaj et *al.,* 2025). Therefore, solid waste management is a very important strategy for finding solutions for the treatment and final disposal of this waste. In Brazil, the National Solid Waste Policy (PNRS) legislation, which dates from 2010 and applies to the entire Brazilian territory, is responsible for defining these actions in an environmentally correct manner (Brazil, 2010).

In many developing countries, electronic waste continues to be managed by informal sectors, people who work independently and without regulation, posing serious risks to public health and the environment. The dangers of exposure to this type of waste, especially for vulnerable groups such as children, have become more evident, highlighting the need for research on the health impacts associated with this practice (Jain *et al.*, 2023).

Recent analyses of efficient e-waste management (Monteiro *et al.*, 2025; Singh *et al.*, 2025) propose strategies for the transition to a circular economy, where the reuse, repair, recycling, and remanufacturing of electronic products promote increased useful life and minimized environmental impacts. However, consumer commitment is essential for the efficiency of well-structured reverse logistics and the recovery of discarded devices. An integrated and collaborative approach reinforces the adoption of sustainable practices.

Electronic waste is an issue that has gained significant relevance in recent years, according to studies by Dias *et al.* (2024), but there is still a need for further research on the topic. One of the gateways to this discussion is basic education, so strategies are needed to integrate the issue into students' daily lives (Silva and Viera, 2021; Souza and Santos, 2022). To this end, there is a need for educational interventions that highlight the importance of conscious consumption, proper disposal of electronic waste, and the socio-environmental consequences that this can generate, with a view to enlightening and raising awareness among students and the school community.

Thus, this study aims to conduct a critical mapping of scientific publications on electronic waste in Basic Education, focusing on the period between 2016 and 2021, in order to identify trends, gaps, and pedagogical practices related to the topic.

INTEGRATIVE REVIEW

NATIONAL SOLID WASTE POLICY (PNRS)

The National Solid Waste Policy (PNRS), Law 12,305, approved on August 2, 2010, and instituted by the Federal Government, is one of the main environmental laws in Brazil and is of paramount importance for the implementation of guidelines, actions, objectives, projects, and instruments regarding the responsible management of Solid Waste (Brazil, 2010). It is worth noting that the PNRS, whose main objective is to reduce the exorbitant volume of waste that ends up in landfills and dumps, is considered a milestone in the country. It was regulated in the same year by Decree No. 7,404/2010 (revoked by Decree No. 10,936/2022). Failure to comply with these duties by public and private entities may result in fines (Brazil, 2010).

In view of this, the aforementioned law is based on the principle of shared responsibility, i.e., not only state, municipal, and federal governments are responsible for waste management, but also companies (the private sector) and society as a whole are responsible for the life cycle of the products they generate. Its actions are not focused solely on environmental protection, but also on the search for new alternatives related to public health, economic, sustainability, and social welfare issues.

According to Santana and Américo (2022), legislation has established that companies are required to implement voluntary drop-off points in the country's major cities by 2025, ensuring the collection and proper disposal of part of the waste generated by their own products. The goal is that at least 17% of the volume sold in 2018 be properly collected and treated, promoting greater responsibility in the productive sector and contributing to reducing the environmental impacts of improper disposal.

According to Ribeiro (2010), defining waste is a complex task, given that it has several sources. In fact, according to the aforementioned author, it is common for people to think that the waste produced by society is useless and worthless. However, when well managed, it has economic value and can be recycled and reused. In addition, it can have "various uses, such as reuse, recycling, composting, recovery, and reuse" (Ribeiro, 2010). Given this,

with proper management regulated by the PNRS, some of these materials can undergo evaluation processes and possibly be transformed, thus avoiding their improper disposal in the environment.

TRASH OR LUXURY? THE IMPORTANCE OF CONSCIOUS AND RESPONSIBLE CONSUMPTION

People have become accustomed to buying more than they need, especially when it comes to cell phones, which are updated every year and become the desire of many young people and teenagers to have this technology in their hands. In fact, this habit of buying excessively and without real need is already ingrained in people's habits.

According to Naspolini and Rossini (2017), shopping has always been present in some form in society, but over time, this habit has changed and given way to consumerism. It is also worth noting that consumerism is driven by large companies and product brands that, in order to attract consumers, invest tirelessly in marketing strategies. With the advancement of technology, this barrage of advertising has gained more space, especially since the emergence of the media.

Consumerism has become one of the main causes of intense environmental degradation, since excessive consumption has intensified waste production and, consequently, the depletion of natural resources, given that many products are strategically designed to be constantly discarded, encouraging consumers to buy more and more, as highlighted by Naspolini and Rossini (2017): "The product is produced to have a short life span. The useful life of the product is deliberately reduced by the industry in order to stimulate consumers and stimulate and drive the industrial market." This process is called planned or programmed obsolescence.

Corroborating this idea of consumerism, authors Leitão, Carvalho, and Barbosa (2023) state that society is being marked by an intense pace of consumption, in which individuals are constantly driven to desire more, quickly replacing products and experiences in search of a satisfaction that is never complete. This economic model transforms desires into needs, fueling a vicious cycle that produces not only material waste but also significant social and environmental impacts.

Given this context, it is essential to promote conscious and responsible consumption, so that people reflect on what they consume, assess the real need for each purchase, and care about the fate of what they discard. In this sense, understanding the mechanics of this rampant consumption helps to highlight how it directly impacts specific environmental problems, such as the growing accumulation of electronic waste, which is one of the greatest contemporary challenges.

The strategy of repetitive consumption created by companies has consequences for the environment (Assumpçao, 2017). One of these consequences is the rapid growth of "electronic waste," resulting from people's lifestyle based on compulsively consuming new cell phones, notebooks, and computers, which, in most cases, are not properly managed after being discarded and become "obsolete." This is precisely the main issue that this article seeks to highlight. It is up to society to become aware and rethink its habits and attitudes regarding the unsustainable development of humanity. This will only be possible through the application of responsible consumption by society.

METHODOLOGY

This study adopts a methodological approach structured in three main stages: Integrative Review, Search and Selection of Articles, and Data Interpretation and Analysis. In the

Search and Selection of Articles stage, specific criteria were used to identify relevant studies that address electronic waste and its environmental impacts.

THE PERSPECTIVE OF THE INTEGRATIVE REVIEW

This work is a qualitative study, based on systematic bibliographic research, which seeks to investigate in an exploratory manner how the topic of "electronic waste" is addressed in basic education. Thus, the integrative review allows for the synthesis of previous research, providing a comprehensive understanding of the topic in question. This methodology is essential for understanding the challenges associated with the improper disposal of electronic waste, which, according to Verma and Prakash (2020) and Bhardwaj *et al.* (2025), can cause serious damage to human health and the environment due to the presence of heavy metals and toxic substances.

3.2 Selection of articles, data analysis, and data interpretation

For this systematic review, we used the Google Scholar data platform, applying inclusion and exclusion criteria to filter the articles found. To locate the studies, specific keywords were used, such as: "electronic waste," "electronic waste and biology teaching," and "electronic waste and school."

Regarding the inclusion criteria, it is worth noting that the articles had to be in Portuguese, published between 2016 and 2021, and classified as scientific articles. At this stage, monographs, dissertations, theses, simple abstracts, and conference proceedings were excluded.

Initially, the titles were analyzed and 30 articles most relevant to the theme were preselected. After that, the abstracts of these previously selected articles were read in order to perform a more detailed analysis and verify those that met the inclusion criteria. After the selection process, only eight remained that contained the research perspective.

Thus, for better interpretation and analysis of the data, the selected articles were organized in a table according to Menezes *et al.* (2018). The study and understanding of the data involved a critical evaluation of the results obtained, aiming to identify patterns and gaps in the existing literature.

RESULTS AND DISCUSSION

Based on the selection of articles as mentioned above, a table was prepared, presenting important data in an organized manner, such as title, authors, year of publication, and objectives (Table 1). After its preparation, a detailed analysis of the selected articles was performed.

TEACHING ENVIRONMENTAL CHEMISTRY: AN APPROACH TO THE INCORRECT DISPOSAL OF ELECTRONIC WASTE FOR STUDENTS IN BASIC EDUCATION

The article aims to discuss the relevance of addressing electronic waste in the basic education curriculum, with a focus on high school students. It also addresses the importance and need for the inclusion of Environmental Education (EE) in the school context, with a view to discussing environmental issues that encourage students to develop critical awareness of their actions and reflect on the environmental consequences of the incorrect disposal of electronic waste.

EE is included in basic education through the National Curriculum Parameters (PCN, 1997), becoming part of all levels and types of education, not as a subject, but being included in an interdisciplinary and cross-cutting manner in accordance with the historical and social context of each school.

TITLE	AUTHORS/YEAR	OBJECTIVES
Teaching environmental chemistry: an approach to the incorrect disposal of electronic waste for elementary school students	Galvão *et al.,* (2021)	Emphasize the importance of electronic waste in the basic education curriculum.
Electronic waste: the disposal of electronic waste in the Itapaci landfill in the eyes of 3rd-year high school students at the Luiz Alves Machado State School	Oliveira e Silva (2021)	Verify students' knowledge about the disposal and intention to dispose of electronic waste correctly.
Improper disposal of electronic waste: environmental damage to the city of Boa Vista – Roraima	Batista *et al.*, (2018)	Diagnose students' knowledge of electronic waste and raise their awareness of the dangers to health and the environment.
Environmental education: an analysis of the proper disposal of e-waste at the Guarabira State School in Paraíba	Silva *et al.*, (2016)	Raise students' awareness of the problems that electronic waste causes to the environment and public health.
School practice of collecting batteries for proper disposal	Silva *et al.,* (2021)	Collect used batteries in two public schools in Humaitá, promoting proper final disposal and avoiding possible environmental impacts
A teaching sequence to address the topic of electronic waste in chemistry classes	Alves *et al.*, (2018)	Propose the design of a teaching sequence to address the topic of electronic waste in high school
Electronic waste in the context of environmental education: approach to the topic by high school teachers	Fraguas *et al.*, (2019)	Analyze and verify whether and how electronic waste is addressed in each school subject
Reverse logistics as a tool for environmental sustainability in a public school	Santos *et al.,* (2020)	Promote reverse logistics for batteries through activities carried out with students at the Reference High School

Table 1. Description of the articles analyzed.

Therefore, working on EA in a single area of knowledge does not allow for a holistic view of all issues related to the environment. For Rodrigues *et al.* (2023), explaining EA by connecting different areas of knowledge allows for the formation of critical, responsible, conscious, and engaged citizens in the preservation and conservation of the environment, and this includes questions related to electronic waste.

ELECTRONIC WASTE: THE DISPOSAL OF ELECTRONIC WASTE IN THE ITAPACI LANDFILL IN THE THE EYES OF 3RD YEAR HIGH SCHOOL STUDENTS AT LUIZ ALVES STATE SCHOOL MACHADO

The article addressed the knowledge of students at a state public school about: what electronic waste is, how to dispose of electronic waste, the correct way to dispose of it, and how to separate this waste from regular trash. The focus was on the local context of the students. To this end, the methodology used was a bibliographic survey on the problem of electronic waste in Brazil and worldwide, as well as the development of a questionnaire with six questions that was applied to three 3rd-year classes in the Chemistry course.

Oliveira and Silva (2021) highlight that the students demonstrated satisfactory knowledge of the topic, as well as the socio-environmental impacts caused by electronic waste when disposed of incorrectly. However, there is still resistance among students to put into practice what was discussed at school. Some

of the students did not show much interest in the topic. Therefore, we believe it is necessary to include Environmental Education in the school curriculum. Thus, as education is a continuous and permanent process, it should not be understood only as a means of transmitting information, but above all as a process of forming values and environmental awareness.

IMPROPER DISPOSAL OF ELECTRONIC WASTE: ENVIRONMENTAL DAMAGE TO THE CITY OF BOA VISTA – RORAIMA

The work of Batista *et al*. (2018) sought to analyze the knowledge of high school students regarding their understanding of electronic waste and its impacts on health and the environment, with regard to proper management.

As a methodology, the authors developed a questionnaire to investigate the students' prior knowledge and, based on the results obtained from the questionnaire, gave a lecture to raise awareness about the topic and encourage behavioral changes regarding the improper disposal of electronic waste and why it should be done properly. It is important to understand that landfills and dumps should not be the final destination for this waste, as it contains various heavy metals that can pose serious risks to the environment and health (Batista *et al.*, 2018).

The authors highlight that a large portion of students were unaware of what electronic waste is, as well as the environmental and human health risks. The authors understand that this may be due to the lack of effective environmental education in schools, as observed in other studies analyzed previously.

ENVIRONMENTAL EDUCATION: AN ANALYSIS OF THE CORRECT DISPOSAL OF E-WASTE AT THE STATE SCHOOL OF GUARABIRA-PB

The work of Silva *et al*. (2016) brings to light the debate on environmental awareness among students at a state public school about the environmental problems caused by electronic waste and the risks to public health. In addition, it sought to guide discussions on the consumption of electronic devices within the school environment.

Silva *et al*. (2016) state that, although the topic of electronic waste is relevant, it was rarely discussed at school. In addition, students were aware of electronic waste but had a superficial understanding of the concepts of recycling, environmental education, and the National Solid Waste Policy (PNRS).

Schools are a fundamental space for incorporating Environmental Education in in a systemic, integrated, and holistic way. There is much to be deconstructed and achieved in these teaching spaces, especially with regard to the interdisciplinary and cross-curricular teaching of Environmental Education in pedagogical practices. In view of this, they also highlight the role of Environmental Education in relation to this issue of electronic waste and advocate the inclusion of EE in school curricula (Silva *et al.*, (2016).

SCHOOL PRACTICE OF COLLECTING BATTERIES FOR PROPER DISPOSAL

Given the issues presented, the main focus of the article by Silva *et al*. (2021) was to discuss the correct disposal of batteries with students from two public schools in the municipality of Humaitá, in the state of Amazonas. The debate about the correct disposal of electronic waste and raising students' awareness of the environmental impacts were key points in the development of the project. Awareness

of the proper management of electronic waste prevented, for example, it from ending up in the municipal landfill.

In general, the authors emphasize the importance of addressing environmental issues from a critical perspective, encouraging students to reflect on how their actions can negatively impact the environment. They also highlight the importance of promoting this debate in schools. As a place for shaping values, schools contribute to behavioral changes and social responsibility toward environmental issues, in addition to educating citizens to be critical and responsible. Giugliani *et al*. (2020) affirm that schools are spaces for collective and participatory action, involving various actors, allowing for the exchange and construction of knowledge, providing experiences of solidarity, the exercise of citizenship, and thus forming more active citizens.

A TEACHING SEQUENCE FOR ADDRESSING THE TOPIC OF ELECTRONIC WASTE IN CHEMISTRY EDUCATION

The work of Alves *et al*. (2018) proposes a teaching sequence to address the topic of electronic waste in high school, focusing on CTS (Science, Technology, and Society). The sequence was entitled "Electronic waste and its social and environmental implications" and sought to discuss consumption, recycling, critical development, disposal, obsolescence, and reuse of electronic waste, as well as to problematize social and environmental issues.

This work highlights the importance of interdisciplinarity in addressing environmental issues. It shows that it is possible and necessary to discuss socio-environmental issues at all levels and in all types of education, not just in specific subjects. As emphasized by Jesus Júnior *et al.* (2023), who argue that interdisciplinarity is an alternative to breaking down fragmented knowledge in the school environment, promoting the integration of knowledge and emancipatory education.

ELECTRONIC WASTE IN THE CONTEXT OF ENVIRONMENTAL EDUCATION: APPROACH TO THE TOPIC BY HIGH SCHOOL TEACHERS

The article by Fraguas *et al*. (2020) discusses the issue of electronic waste from an environmental education (EE) perspective, with the aim of assessing how and in what ways (use of methodologies) high school teachers address this topic in their classes. To obtain relevant data, interviews were conducted with each teacher and their respective areas of expertise.

Finally, it was found that teachers seek to work on the topic of electronic waste in their classes, even if some subjects only touch on it superficially. Furthermore, they consider it interesting to work on EE, electronic waste, and consumerism in their classes, and they were able to reflect on how it is possible to improve and broaden discussions on this topic, which is so necessary at the present time.

Based on the above, Costa and Aguiar (2020) affirm that EA favors the construction of an environmentally just society. To this end, it is essential that its practice be developed in the daily life of the school and enable a participatory process in the defense of the environment, in order to form students who are critical and reflective about their reality, preparing them to become active and transformative citizens. In addition, for this to happen, it is necessary to train environmental educators capable of working with EA in basic education schools, requiring the reformulation and restructuring of both initial teacher training courses and continuing education courses, so that this theme increasingly becomes part of educational institutions (Diniz and Ahlert, 2021).

REVERSE LOGISTICS AS AN INSTRUMENT OF ENVIRONMENTAL SUSTAINABILITY IN A PUBLIC SCHOOL

The work carried out by Santos *et al*. (2020) was a descriptive, qualitative and quantitative field study in which a questionnaire was administered to teachers and students in the 1st to 3rd years of high school and in Youth and Adult Education. Based on the responses obtained, the authors point out that the topic of reverse logistics in this school has not yet been the target of actions related to Environmental Education. Environmental education in schools is considered and recognized as the most appropriate place to sensitize and raise awareness among an unlimited number of individuals about their citizenship, which makes it indispensable for the complete formation of conscious individuals (Soares et *al.,* 2007). In this case, working on environmental education in schools becomes of paramount importance.

FINAL CONSIDERATIONS

This study allowed us to understand how the issue of electronic waste is addressed in the school context, highlighting its relevance in view of the socio-environmental impacts of the improper disposal of this waste. The analysis revealed that, although there are a significant number of articles dealing with the topic in basic education, there is still a need to expand related research and pedagogical practices, considering the growing production of electronic waste and its harmful effects on the environment and public health, requiring that they transcend theoretical teaching, incorporating practical activities and projects that involve the school community, aiming at the formation of conscious citizens committed to sustainability.

It was also observed that the topic of electronic waste is interdisciplinary in nature, being addressed not only in geography and biology classes, but also in chemistry, science, and information technology, promoting a more holistic and critical understanding among students. The integration of this theme into the school curriculum is fundamental for strengthening Environmental Education, which, although provided for in educational guidelines, still faces challenges in its effective implementation and consolidation in teaching practices.

In addition, initiatives such as intervention projects and practical activities have proven to be effective in raising student awareness, promoting behavioral changes, and encouraging social and environmental responsibility. Such actions contribute to the formation of conscious citizens who are engaged in the search for sustainable solutions to contemporary environmental problems. Therefore, this study did not intend to exhaust the topic, but rather to contribute to reflection and encourage future research and educational practices that promote awareness about electronic waste and its impacts, strengthening Environmental Education as an instrument of social transformation.

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