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Article

Environmental Education and Sustainable Practices: Implementation of an Electronic Waste Collection Point at the State University of Minas Gerais/*Frutal* Campus

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ABSTRACT
The growth of electronic waste due to rising consumer demand challenges public health and the environment due to toxic substances. Therefore, the objective of this study was to implement an ecopoint dedicated to the disposal of this waste at the State University of Minas Gerais (UEMG) in the city of Frutal-MG, aiming to raise awareness, educate, and engage with the local population of the municipality and its region. Using action research as a methodology, knowledge about electronic waste was condensed into an educational brochure . The study was conducted in partnership with UEMG/FRUTAL-MG, the Association of Recyclable Material Collectors of Frutal, the Secretariat of the Environment, as well as private companies and local agencies. The impact of the alliance between academic institutions, the public sector, and civil society for sustainable initiatives was highlighted, with the aim of proposing that electronic waste be disposed of at the UEMG recycling center so that it can reach a sustainable end, with the participation of the academic community, the local population of Frutal and society in general. Finally, at the end of the second academic semester of 2023, several containers were acquired and securely installed at a location designated by the UEMG administration.
Keywords: electronic waste; sustainability; environmental management.

RESUMO
O crescimento do lixo eletrônico por crescente consumismo, desafia a saúde pública e o meio ambiente devido às substâncias tóxicas. Sendo assim, o objetivo deste trabalho foi implantar um ecoponto dedicado ao descarte desses resíduos, na Universidade do Estado de Minas Gerais (UEMG) na cidade de Frutal-MG, visando sensibilizar, instruir e colaborar com a população do município e região. Tendo como metodologia a pesquisa-ação, os conhecimentos sobre lixo eletrônico foram condensados em um folder (*Brochure*) educativo. O estudo teve a parceria da UEMG/FRUTAL-MG, Associação de Catadores de Materiais Recicláveis de Frutal, Secretaria do Meio Ambiente, além de empresas privadas e órgãos locais. destacou-se o impacto da aliança entre instituições acadêmicas, setor público e sociedade civil para iniciativas sustentáveis, com o fim de propor que o lixo eletrônico possa ser descartado no referido ecoponto da UEMG para que alcance um fim sustentável, com a participação da comunidade acadêmica e sociedade em geral. Por fim, no final do segundo semestre acadêmico de 2023, foram adquiridos e fixados em local próprio e indicado pela administração da UEMG, alguns containers para tal finalidade.
Palavras-Chaves: resíduos eletrônicos; sustentabilidade; gestão ambiental.

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Introduction

Electronic waste, generated annually in millions of tons, represents solid waste that triggers serious environmental, legal, and social impacts due to its composition. Population growth and technological advances, despite the benefits they have brought, exert significant pressure on natural resources, ecosystem services, and sustainability systems (Kitajima *et al.*, 2019). In the context of capitalist dynamics, the constant disposability of goods and commodities stimulates the consumption of new products.

Forti *et al.* (2020) argue that rapid technological evolution and the introduction of new models encourage the constant replacement of devices, thus increasing the volume of electronic waste. According to Baldé *et al.* (2017), electronic waste, or e-waste, is the term used to describe all electrical and electronic equipment (EEE) and its parts that have been discarded by their owners as waste, with no intention of being reused.

In this context,, e-waste is also known as waste electrical and electronic equipment (WEEE), electronic waste, or e-waste in various regions and contexts around the world. This category encompasses a wide range of products, virtually any household or commercial item that contains electrical circuits or components with a power source or battery (Baldé *et al.*, 2017).

Accordingly, "The Global E-waste Monitor 2017" (Baldé *et al.*, 2017) divides this product classification into six categories, as follows:

- **Temperature-exchange equipment** (refrigeration and freezing appliances, e.g., refrigerators and freezers)/
- **Screens and monitors** (televisions, computer screens, laptops and tablets);
- **Lamps** (fluorescent lamps, high-intensity discharge lamps and LED lamps);
- **Large household appliances** (e.g., washing machines, clothes dryers, dishwashers);
- **Small household appliances** (e.g., vacuum cleaners, toasters, radios);
- **Information and communication technology (ICT) equipment and small IT & telecommunications equipment** (e.g., computers, laptops, tablets, mobile phones, routers, pocket calculators).

Thus, the environmental problems associated with this range of waste are caused by its improper disposal, often in open dumps or controlled landfills. This practice exposes electronic materials to atmospheric action, causing the deterioration of their components and releasing constituent elements into the environment. For this reason, improper disposal of e-waste can contaminate groundwater and terrestrial and aquatic ecosystems, affecting the health and well-being of people who come into contact with this electronic waste (Maciel, 2011; Kitajima *et al.*, 2019).

One of the main factors contributing to adverse effects is the toxic metals added to electronic components, which, when disposed of improperly, are harmful to the environment and human health. According to Bosquesi and Ferreira (2018), discarded electronic devices contain toxic substances such as lead and cadmium, which are harmful to soil and water. Batteries, fluorescent lamps, and other electronic components may also contain mercury (UNIDO, 2020), which in turn also contaminates the environment.

The batteries in electronic devices contain lead. When disposed of incorrectly, leakage and aquatic or terrestrial contamination can occur. As for human health, exposure to lead can cause damage to the nervous system, cognitive impairment, and kidney problems (Ribeiro *et al.*, 2019). Cadmium, on the other hand, is found in rechargeable batteries, circuits, and semiconductors and is a potential soil pollutant. Furthermore, exposure to cadmium can cause kidney damage, respiratory problems, and increase the risk of cancer (Freitas, 2010).

Furthermore, the above-mentioned substances are neurotoxins and can cause damage to the nervous system, especially in children and developing fetuses (Maciel, 2011), a warning supported by the World Health Organization (WHO, 2021). In short, there are many harmful effects on human health related to the improper disposal of electronic waste, such as skin, eye, and mucous membrane irritation, respiratory, renal, neurological, hepatic, and reproductive problems, allergies, cancer, genetic mutations, and death.

Therefore, it is important to highlight that such effects can be caused by direct exposure to electronic waste, by ingestion or inhalation of substances released into the environment, or by the food chain (Franco *et al.,* 2021). Therefore, the control of electronic waste disposal comprises a set of actions directly linked to

sustainability. In this context, the approach to addressing this challenge involves recycling, reuse, and proper disposal, which can be achieved by raising awareness in society, in accordance with the principles established in legislation (Kitajima *et al.*, 2019).

With the growing production of waste electrical and electronic equipment (WEEE), the National Environment Council (CONAMA) approved CONAMA Resolution No. 257 on June 30, 1999. This establishes mandatory procedures for the reuse, recycling, treatment, or environmentally sound final disposal of batteries containing lead, cadmium, mercury, and their compounds (MMA, 1999).

In 2008, CONAMA instituted Resolution No. 401 (Brazil, 2008), later amended by Resolution No. 424 of 2010. This regulation stipulates that points of sale for batteries must offer collection points to consumers, forwarding the products to the manufacturers responsible for recycling (Brazil, 2010a). The National Solid Waste Policy, Law No. 12,305/2010, was regulated by Decree No. 7,404 of 2010 and established the National Solid Waste Plan as one of its main instruments (Brazil, 2010b).

In September 2015, Brazil committed to implementing the 2030 Agenda for Sustainable Development (UN, c2024), which highlights Sustainable Development Goal (SDG) number 12, focused on sustainable production and consumption. This includes global and local actions to achieve efficient use of natural resources, responsible management of chemical waste, and reduction of waste generation through prevention, reduction, recycling, and reuse.

On February 12, 2020, Decree 10.240 was signed to regulate the reverse logistics of electronic products, i.e., it requires companies in the sector to implement collection systems for this waste and ensure its correct disposal. Chapter XIV, Art. 49, stipulates a period of five years from the date of publication to structure and implement the reverse logistics system (Brazil, 2020).

According to a report released by the United Nations (UN) in 2019, Brazil is the fifth largest producer of electronic waste in the world, with 2 million tons of this material per year. According to the survey, only 3% of this waste is recycled (Forti *et al.*, 2020). In the Brazilian context, Bosquesi and Ferreira (2018) argue that the lack of adequate infrastructure for the treatment of electronic waste is an imminent challenge faced by society.

In view of this, public policies and raising awareness in society are topics addressed by authors such as Dias (2009), who focus on the effective implementation of regulations and the promotion of shared responsibility, essential actions for dealing with the problem. The importance of environmental education (EE) stands out, which aims to develop social values, knowledge, skills, attitudes, and competencies, both individual and collective, focused on preserving the environment (Freitas and Oliveira, 2021).

Thus, it became necessary to implement the ecopoint as a strategy to promote responsibility for environmental preservation, mitigate impacts on human health, and promote environmental education in the academic community, as well as among citizens in general, in the municipality of Frutal-MG, where UEMG/Frutal Unit is located.

The municipality of Frutal, located in the interior of Minas Gerais, in the Triângulo Mineiro region, is small and has a population of approximately 58,588 inhabitants (IBGE, 2022). In the region, the selective waste collection system has been managed by the Association of Recyclable Material Collectors of the Municipality of Frutal (ASCAFRU) since 2018. This association operates under the auspices of the Frutal Environment Secretariat (SEMMA).

Thus, it is understood that the implementation of an electronic waste collection point at the State University of Minas Gerais for the residents of the city of Frutal/MG will provide a suitable location for the ideal disposal of electronic waste, as well as promote environmental education.

Methodology

The methodology adopted in this project was field research based on the action research method. Thiollent (2022) defines this method as:

> [...] a type of empirical social research that is designed and carried out in close association with an action or the resolution of a collective problem and in which researchers and participants representative of the situation or problem are involved in a cooperative or participatory manner (Thiollent, 2022, p. 14).

This study also draws on bibliographic research, serving as a literature review to collect and analyze previously published work on the subject. In the field of education and science, bibliographic research is undoubtedly a cornerstone, as it provides access to all the libraries that, over the centuries, have developed and accumulated an enormous volume of knowledge. It is a method that, according to Pizzani et al. (2012), enables researchers to build upon previous findings and advance theoretical discussions.

To this end, there are several research techniques and procedures that can be used to identify and locate previously published scientific works. Scholars are able to investigate relevant literature and detect information gaps in the current state of the field under analysis while uncovering new propositions (Lima and Mioto, 2007). Therefore, using bibliographic research becomes a scientific strategy to further expand the the scope of the topic.

Creation of the recycling center: dialogue between partners

Initially, there was a partnership between the project members, the State University of Minas Gerais (UEMG), Frutal unit, and the Association of Recyclable Material Collectors of the Municipality of Frutal (ASCAFRU). The action was specifically aimed at the inhabitants of the municipality of Frutal, in Minas Gerais, with the aim of engaging and raising awareness among a wide spectrum of residents, covering various age groups and socio- . The purpose was to promote environmental education, a crucial element for commitment to environmental preservation.

The waste accepted includes light bulbs, CPU boards, notebook boards, smartphones, tablets, and laptops. The electronic waste collected at the UEMG recycling point will be sent to ASCAFRU, which is responsible for its correct disposal to companies specializing in recycling and treatment of electronic waste. *Periodically, data related to the amount collected at the recycling point will be* collected and analyzed to monitor activities, aiming at the efficiency of the initiative.

Training of members and mobilization

Several meetings were held with ASCAFRU employees and recyclable material collectors to discuss the demand for electronic waste, the difficulties in the collection process, the correct handling methods, and to define with the recyclers the best way to operationalize the project's development, in partnership with the Frutal Department of the Environment. With the support of companies, an ecopoint was set up at the State University of Minas Gerais.

In addition, informational and educational material was developed to raise awareness of the issue among the population; a virtual brochure was chosen—a website entitled "Ecoponto Tech." The project was also publicized through local radio stations and other media outlets, such as newspapers and the UEMG/Frutal website, to help spread the word about the project in the municipality. It is worth noting that a space was created on the UEMG *website* to answer questions and provide additional relevant information about the ecopoint.

Results and discussion

Electronic waste and the environmental dimension

In recent years, the demand for electronic goods has increased. It is evident how the process of globalization is linked to the search for technological improvements to manufacture increasingly powerful devices. As a result, the consumer market has generated high proportions of electronic equipment disposal, such as televisions, computers, cell phones, tablets, batteries, lamps, among other materials, designated as electronic waste.

To curb the enormous damage related to this issue, environmental education is important to generate behavioral change in society and promote sustainable practices. According to Leal Filho *et al.* (2021), the integration of environmental concepts contributes to the formation of conscious citizens capable of adopting responsible behaviors in relation to the environment.

Similarly, Jacob (2003) argues that the environmental dimension is increasingly present in the educational universe. It involves different actors and knowledge systems, promoting an interdisciplinary perspective. The same author emphasizes that environmental education must be critical and innovative, seeking social transformation.

In view of this, it is crucial that measures be taken to address the issue of electronic waste, such as:

- **Awareness and regulation**: educating the community as a whole about the importance of proper disposal and implementing laws that encourage recycling, as these are fundamental to changing behaviors and ensuring sustainable practices. Some examples are awareness campaigns, workshops, and environmental education centers, highlighting the harm that this waste causes to the environment and human health;
- **Reuse of devices**: reuse is an efficient way to reduce electronic waste by giving it new purposes and functions;
- **Increased durability of electronic products**: the greater the durability of the electronic product, the better the reduction in the amount of waste generated, a fact that is in line with the circular economy;
- **Proper recycling of electronic waste**: recycling will contribute to reducing environmental impacts, since the practice allows for the recovery of valuable metals, such as gold, silver, and copper, which can be reused in new products (Ferreira & Rodrigues, 2012);

Environmental education and sustainable practices

Environmental education represents the process by which individuals and groups build values, knowledge, attitudes, and skills aimed at preserving the environment, an essential asset for quality of life. In this context, communication plays a crucial role in raising environmental awareness. Thus, language is expressed through texts, which emerge from various human activities (Paula & Carvalho, 2014).

Within this context, this work is configured as a practice of environmental education, using the textual genre of the brochure as an educational tool. According to Karwoski (2005), the brochure is defined by its social function and presentation format, being produced in specific contexts with well-defined discursive objectives. The careful choice of this type of discourse, made by the sender, considered someone responsible for the conception, creation, or production of the brochure , contributes to the realization of the discursive purpose and determines the structure of the content presented.

The Brochure as an Environmental Education Tool

Through research conducted in the Google Scholar, SciELO, and Capes Periodicals databases, articles were collected that directly addressed the proper disposal of electronic waste and the implementation of recycling points as their central theme. After selecting, reading, and analyzing the publications, the brochure was created using the online graphic design platform Canva.

The brochure addressed the concepts of electronic waste and recycling points, their location, opening hours, accepted waste, and disposal instructions. These instructions are essential for preparing waste for disposal at recycling points and achieving the expected results. In addition, informing the public about the final destination of the collected waste demonstrates the seriousness of the project.

Thus, the impacts of toxic substances from electronic waste on the environment, the health damage caused by exposure to these elements, and the correct ways to dispose of them were listed. Finally, it contained information regarding contacts, project members, and supporting companies.

The first part of the brochure was reserved for the main subject, and The cover page combined visual and textual elements that communicated the content to be addressed to the reader in a simple and accessible way. The name chosen for the project was "Ecoponto Tech," with the phrase "sustainable disposal at UEMG." The color chosen for the material was orange, as it symbolizes hazardous waste (Brazil, 2001), which includes electronic waste, materials that require specialized treatment and final disposal.

Initially, the concept of electronic waste was presented as referring to any discarded electronic equipment or device, and ecoponto as the place designated for the selective collection of specific waste, important definitions to instruct the reader. The second part of the brochure provided information on the main impacts on the environment and human health caused by exposure to toxic substances present in electronic waste, such

as lead, copper, arsenic, mercury, cadmium, and aluminum, according to the concepts of the authors mentioned above.

In addition, ways to properly dispose of electronic waste were added, such as recycling programs, specialized collection, recycling centers, and some manufacturers that accept used devices. Such discussions help raise public awareness about the damage, with the aim of prevention.

The educational material was disseminated online using UEMG websites, such as the official website, Facebook, and Instagram, to the target audience, namely the academic community of UEMG/Frutal, as well as the community in general, in this case the population of the municipality of Frutal/MG. Figures 1 and 2 show the final version of the brochure .

Website development as a dissemination strategy

The "Ecoponto Tech" website (http://www.ecoponto.tec.br) was developed to provide detailed information about electronic waste and the operation of the recycling center located at UEMG. This virtual resource provides essential data, such as opening hours and contact options. The home page (Figure 3) contains information about the nature of electronic waste, the purpose of the ecopoint, the types of electronic waste accepted (with specific references), and the importance of proper disposal of these materials.

Additionally, the main page displays detailed instructions for preparing for disposal, including:

- **Turn off devices:** make sure all electronics are turned off before disposal;
- **Remove personal data:** back up and delete any personal and confidential information from the devices;
- **Separate components:** disassemble items such as batteries, wires, and accessories.

In addition to information about the project's recycling center, the website has a section with informative articles on electronic waste disposal, addressing environmental pollution, health issues, proper disposal methods, recycling and specialized collection programs, and partnerships with manufacturers (Figure 4).

Finally, the website has a contact page (Figure 5), where visitors can send messages directly through a form and find the location of the recycling point via Google Maps.

Training of members of the Association of Recyclable Material Collectors of the Municipality of Frutal (ASCAFRU)

Environmental education plays an important role in building a society that is conscious and committed to sustainable practices, especially with regard to the challenge of electronic waste in today's world (Ferreira, 2017). Among environmental education strategies, training is one of the existing actions.

The training was held at ASCAFRU's premises, with a slide presentation, and was divided into the following stages:

- Sensitization and awareness of the concepts of electronic waste, presentation of the environmental and social impacts of electronic waste;
- Identification of electronic waste through training in the recognition of different types of equipment;
- Dissemination of knowledge about the hazardous and valuable components present in accepted waste, such as lamps, CPU boards, notebook boards, cell phones, tablets, and laptops, at the recycling center at the State University of Minas Gerais (UEMG/Frutal);
- Safety and health were addressed through concepts of protective measures when handling electronic waste, as well as the proper use of personal protective equipment, in order to avoid exposure to waste contamination, since it contains toxic substances;
- In terms of transportation, ASCAFRU coordinated the organization of routes for weekly waste collection at the recycling center, which was scheduled for every Tuesday.

The steps described above aimed to train members to handle electronic waste safely and sustainably, with the goal of promoting proper recycling practices. Thus, it is essential to promote and encourage environmental education programs, both in formal and informal education.

The practice of environmental education suggests that behavioral change occurs through information, reflection, active participation, and cooperation between different entities. Consequently, this responsibility exercises citizenship in environmental causes, with the aim of achieving significant and promising results in reducing pollution and contamination by toxic substances from electronic waste, which are harmful to the environment and human health (Kitajima *et al.* 2019).

Implementation of the recycling center

The recycling point for the disposal of electronic waste was implemented on December 20, 2023, at the State University of Minas Gerais (UEMG) in the municipality of Frutal-MG.

For the implementation of the recycling point, two metal cans with a capacity of 200 liters each were purchased. The cans received the appropriate treatment before painting. Studies determined that the ideal color would be orange, as it refers to hazardous waste, according to CONAMA Resolution No. 275 of 2003, which stipulates the color code for identifying the various categories of waste. This category is directly related to electronic waste, which is made of toxic components.

Next, a metal door (lid) was adapted to the top of the cans, equipped with a handle to facilitate opening. This change aims to keep the cans closed, preventing exposure of the materials contained therein. In addition, stickers were made with information about the sponsors, identification of the electronic waste accepted at the recycling point, and information about the toxic substances present in this waste.

After approval by the property department of the UEMG university in Frutal, some recommendations were requested, such as ensuring proper signage and identification of the location of the cans, in a ventilated outdoor area, conducting regular inspections to ensure that their maximum capacity is not exceeded, and preventing the leakage of liquids from discarded electronics. Based on this, the cans were installed in the outdoor area of the Foyer, in Block A (Figure 6), and the locations were properly marked.

Companies supporting the project

In developing the project, private sector companies were recruited to participate with the aim of contributing to sustainability and social and environmental responsibility. The initiatives analyzed in the business history of these companies showed that, through strategic partnerships and coordinated actions, it was possible to raise public awareness to reduce environmental impacts and promote social inclusion. These companies (Figure 7) promote social and digital inclusion, training individuals for the job market and fostering the circular economy. It should be noted that collaboration between companies, government, and civil society is essential to expand the reach of these initiatives and promote lasting behavioral changes.

Publicizing the initiative in the region

Ecoponto Tech has been promoted on the aforementioned website, on the social media (Facebook and Instagram) of the Frutal unit of the State University of Minas Gerais (UEMG), on the local radio station Rádio 97 FM Frutal, in the print newspaper Jornal Pontal, and on the Ecoponto Tech website itself. Due to this mix of digital and physical dissemination, between modern and traditional media, the popularization of scientific content is more likely to happen in a short time.

The web leads an advantageous position as an effective means of communication, serving as a tool to enable mass understanding of debates and creating a link between common sense and science (Noruzi, 2008). At the same time, Bueno (2010) emphasizes that the dissemination of scientific knowledge, which begins in academic environments, must also reach the external community through scientific journalism, carried out by radio stations, newspapers, and other traditional media.

Conclusions

As presented, electronic waste is a critical issue that this study addressed in a multifaceted way, focusing on environmental education and the implementation of practical disposal solutions. One of the most important parts of this project was to train members of the Association of Recyclable Material Collectors of Frutal

(ASCAFRU) by raising awareness about what electronic waste is, how to recognize it, and disseminating information about its hazardous and valuable components, safety and health measures, and transportation logistics.

The scope of the project was to implement an ecopoint at the State University of Minas Gerais (UEMG) in December 2023 by installing metal containers for the disposal of electronic waste. These were carefully prepared and labeled to ensure the safety and effectiveness of the project. The approval and guidance of the university's culture unit played a special role in their correct positioning.

At the same time, an informational brochure and the Ecoponto Tech website were created, which are fundamental tools for disseminating essential information about the proper disposal of electronic waste. In this way, details about this sustainable practice are easily disseminated among the population, presenting key concepts and practical instructions on environmental impacts. Both solutions aim to raise awareness and mobilize residents about responsible disposal, contributing to the promotion of sustainable practices and mitigation of the negative impacts of electronic waste on the environment and public health.

We believe there is a need to continue and expand this project. To this end, we welcome the participation of other private institutions as a way to promote the expansion of the project, which will boost the collective commitment to responsible environmental management. A strategic alternative is to encourage the extension of environmental education work in municipal and high schools.

This project illustrated the intersection of environmental education, inter-institutional collaboration, and public sector support in addressing the challenge of electronic waste through continuous efforts and cooperation, thus demonstrating that progress can be made toward a more sustainable future.

Similar initiatives can be implemented in different regions of the country, contributing to environmental awareness and reducing the negative impacts caused by the improper disposal of electronic waste . Such expansion requires not only the engagement of different actors, but also the adaptation of the project to the specificities of each locality, considering regional needs and characteristics.

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