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CONTRIBUTIONS TO SUSTAINABILITY IN TECHNICAL EDUCATION: REUSE OF CONSTRUCTION WASTE AS A WAY TO REDUCE ENVIRONMENTAL IMPACT

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João Hermem Fagundes Tozatto[1]

ABSTRACT
The present study investigates the impact of the reuse of solid waste generated during the practical classes of the Technical Course in Civil Construction at CEFET-RJ. The main objective is to analyze how sustainable pedagogical practices can reduce the environmental impact of the civil construction sector, simultaneously empowering students to face global sustainability challenges in the sector. The research used quantitative and qualitative methods to evaluate the efficiency of the reuse of materials, such as 'argalama' mortar and PVC pipes, in two different laboratories: Masonry and Hydraulic Installations. The results show that these practices, once the obstacles are overcome, can reduce the costs of materials and the consumption of natural resources, such as water and energy, without compromising the quality of the teaching activities. The conclusions indicate that the integration of sustainable practices in technical education not only contributes to the training of professionals with greater environmental awareness, but also enables the development of solutions with this approach in real construction projects. The study highlights the relevance of technical education as an agent of transformation in the context of sustainability, in line with Sustainable Development Goals (SDGs) 4 and 12.

Keywords: Civil Construction. Vocational Education. Reuse. Construction and Demolition Waste. Sustainable Development Goals.

[1]Dr. in Civil Engineering
Federal Center for Technological Education Celso Suckow da Fonseca (CEFET-RJ)
Email: joao.tozatto@cefet-rj.br
ORCID: https://orcid.org/0000-0003-1814-0434
LATTES: http://lattes.cnpq.br/6253334950281588

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INTRODUCTION

In recent decades, there has been a growing concern about climate change and the environmental degradation of the planet. This scenario has driven the development of policies and actions aimed at the concept of sustainable development. International organizations, such as the United Nations, for example, seek to encourage practices that promote the integration of environmental issues into economic development, as evidenced in Agenda 21. This document recognizes that population growth, associated with increased industrial production and the intensive exploitation of natural resources, has accelerated the degradation of ecosystems, putting global well-being at risk (UNITED NATIONS, 1992). The civil construction sector, as one of the largest generators of solid waste, plays a significant role in this scenario (BRASIL, 2010b).

The Intergovernmental Panel on Climate Change (IPCC, 2022) points out that the emission of greenhouse gases, such as carbon dioxide (CO_2) and methane (CH_4), from the decomposition of solid waste, is one of the main factors contributing to global warming. In this context, the construction industry stands out as one of the largest generators of waste, both in urban and rural areas.

According to the 2021 Thematic Diagnosis on Urban Solid Waste Management, civil construction waste continues to be one of the largest components of urban solid waste, representing a significant portion of the waste generated in urban areas in Brazil. Estimates indicate that Construction and Demolition Waste (CDW) corresponds to a significant portion, ranging from 51% to 70% of the total urban solid waste generated in the main urban centers of the country. These percentages show the substantial impact of the civil construction sector on waste generation in Brazil (BRASIL, 2021).

The implementation of sustainable policies, especially in developing countries, faces significant economic and social challenges. In Brazil, the National Solid Waste Policy (PNRS), established in 2010, aims to promote integrated waste management and encourage recycling. However, although the PNRS has provided advances, its implementation faces obstacles, such as the lack of infrastructure in several regions and the difficulty of integrating the policy objectives with the local challenges faced by smaller municipalities (BRASIL, 2021; BRAZIL, 2010b). Studies show that, although 95% of Brazilian municipalities have established solid waste management plans, only 35% have been able to implement them effectively due to budget limitations and lack of technical capacity (BRASIL, 2020a).

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Brazil does not face this challenge in isolation. In emerging countries such as South Africa, the implementation of environmental policies, especially in the solid waste sector, also encounters significant obstacles. Although there is a defined political structure, the lack of financial resources and poor monitoring compromise the results. In addition, there is a disconnect between national policies and local realities, making it difficult for small construction enterprises to adopt sustainable practices (GODFREY et al., 2020).

This scenario highlights the need for more adaptive and decentralized policies that consider local particularities and provide adequate financial and technical support, both in Brazil and in other emerging countries. The construction sector has been seeking innovative solutions, including tax incentives and specific credit lines for recycling and waste management projects, aiming to overcome implementation barriers (HAITHERALI and ANJALI, 2024; RAHMAN et al., 2021).

In the educational context, the integration of sustainable practices in technical laboratories has been explored. Studies indicate that the reuse of construction waste can not only reduce the volume of waste generated, but also act as an effective pedagogical tool. In addition, students' awareness of the life cycle of materials and the environmental impact of practical activities directly contributes to the creation of a culture of sustainability in the civil construction sector (BATISTA et al, 2015; SIMONA, 2023).

The integration of sustainability into the pedagogical environment, particularly in technical and vocational courses, offers a unique opportunity for future professionals to acquire a more holistic understanding of environmental problems and develop the necessary skills to implement innovative solutions. Transdisciplinarity, in particular, provides a path for different areas of knowledge to collaborate, allowing students to establish connections between the exact and social sciences and develop a critical view of the environmental implications of construction practices (MORIN, 2000).

Environmental education at the high school level is directly relevant to student training, especially in technical courses focused on civil construction. According to UNESCO, it contributes to the development of critical skills and awareness of global environmental challenges, encouraging young people to participate in the search for sustainable solutions (UNESCO, 2017). This phase of the educational process is an opportune moment to introduce concepts such as recycling, reuse of materials, and environmental responsibility, elements that influence their future professional choices (ALTASSAN, 2023; CROSSLAND, 2024).

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In Brazil, the National Curriculum Guidelines for Environmental Education (DCNEA) emphasize the need to incorporate sustainable practices into the school curriculum, focusing on interdisciplinary approaches and practical methods to address environmental issues (BRASIL, 2012; BRASIL, 1999). In civil construction, this technical and environmental training allows students to understand the environmental impacts of their professional activities. Additionally, it promotes the understanding of the life cycle of materials and the use of more sustainable technologies, preparing students to deal with the challenges of the sector (SANDANAYAKE et al., 2022; WEIRS and OSBORNE, 2020).

At CEFET-RJ, this approach is integrated into pedagogical practices, with an emphasis on experimentation in civil construction laboratories (BRASIL, 2020b). The use of recycled waste, such as argalama, demonstrates how students can learn to apply sustainable solutions in the exercise of their duties. This transdisciplinary practice allows students to find solutions to the sector's environmental challenges and understand the implications of their decisions (SCHÜTZENHOFER et al., 2022).

This article aims to analyze the impact of the reuse of solid waste generated in the practical classes of the technical course in civil construction at CEFET-RJ. Based on a review of the procedures used in the laboratories, recycling and reuse solutions were proposed that aim to reduce the volume of waste generated and maximize the use of recycled inputs. This approach aligns with global circular economy and sustainability education practices.

METHODOLOGY

The present study was conducted using quantitative and qualitative approaches to analyze the materials and procedures used during practical classes in some laboratories of the Civil Construction course at CEFET-RJ. The following methodology was adopted:

JUSTIFICATION FOR SAMPLING

The selection of the Masonry and Hydraulic Installations Laboratories for this study was based on specific criteria. First, these laboratories represent fundamental areas in technical training in civil construction, offering a comprehensive view of the sector's practices. In addition, these environments generate a significant variety of waste, providing robust opportunities for the implementation and evaluation of reuse practices. The choice also considered the frequency of use of these laboratories in the curriculum, ensuring an

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adequate volume of data for analysis during the study period and the affinity of the selected researchers with these disciplines.

PERIOD AND CONTEXT OF THE STUDY

This study was based on scientific initiation projects at the high school level, conducted within the scope of the Institutional Program of Scientific Initiation Scholarships for High School (PIBIC-EM). These projects represented the initial results of the broader research project entitled "Reuse of Solid Waste from Civil Construction Applied to the Pedagogical Environment", started in 2008.

The projects were selected through a specific public notice and received funding for their execution. The research was carried out over a period of one year, from 2008 to 2009, with the participation of selected scholarship students. This time interval allowed a complete observation of an annual cycle of practical classes, covering different classes and academic periods. The duration of the study enabled a comprehensive analysis of reuse and waste generation practices over two academic semesters, capturing curricular and operational variations of the laboratories during a full academic year.

QUANTITATIVE AND QUALITATIVE DATA COLLECTION

Initially, a comprehensive survey was carried out to collect data on the materials, methods and equipment used in laboratory activities. This process involved direct observation and interviews with the professors responsible for the laboratory practices. The participating professors consented, through their testimonies, to collaborate with the study. The interview process was conducted ensuring confidentiality, and the data collected went through a process to preserve the privacy of those involved. In addition, the research team examined the Pedagogical Project of the Course (PPC) of the Technical Courses in Buildings and Roads of CEFET-RJ. The Civil Construction Coordination, representing the course management team, provided access to the laboratory practices booklet. This valuable resource detailed the materials, equipment, and procedures for each hands-on lesson.

Based on this information, it was possible to map the laboratory practices of each discipline, relating them to the inputs and equipment used, as well as the waste generated. The focus was on identifying the main materials and equipment consumed during classes, the amount of solid waste produced and opportunities to optimize the use of resources. This

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initial phase provided the basis for the subsequent analysis and the proposition of more sustainable practices.

ANALYSIS AND OPTIMIZATION OF RESOURCE USE

After data collection, the research team analyzed the information gathered to propose alternative practices aimed at optimizing the use of resources. This phase included the evaluation of recycling or reuse strategies for the materials involved, such as construction waste, as well as the consideration of waste reduction during laboratory activities. The analysis also involved discussions with teachers to identify good practices that could contribute to a more sustainable use of resources.

DATA ANALYSIS APPROACH

The analysis of the collected data was conducted using a mixed-methods approach. For quantitative data, Excel and Word software were used for tabulation and descriptive statistical analysis, including calculations of means, percentages and frequencies of material use and waste generation. The qualitative analysis of the interviews and observations was carried out through thematic coding, identifying recurrent patterns and themes related to sustainable practices, categorizing different types of waste generated and reuse strategies, grouping observations on the behavior of students in relation to sustainable practices and implementation challenges. This process was carried out manually, allowing a deep immersion in the data and a contextual interpretation of the information obtained.

VALIDATION OF RESULTS

The validation of the results of this study was conducted by comparing the information obtained in interviews with professors, laboratory observations, and analysis of course plans. The preliminary results were presented at internal seminars of CEFET-RJ. This process allowed the refinement of the interpretation of the data and the strengthening of the study's conclusions. The results were also compared with the literature on sustainable practices in technical education and waste management in civil construction.

INTEGRATION OF RECYCLED MATERIALS INTO LABORATORY PRACTICES

The research also sought to identify other laboratory courses at CEFET-RJ where Civil Construction Waste (RCC) could be reused as raw material. Special attention was devoted to establishing connections between different courses, exploring how transdisciplinary approaches could lead to innovative solutions in the management and reuse of materials. By integrating RCC into laboratory activities, the goal was to demonstrate the practical applications of recycling in an educational context.

The Civil Construction Area of CEFET-RJ has eight laboratory spaces in its Pavilion for student training, aiming to replicate some environments that future professionals will find in their practical life. These laboratories are:

- Frame Laboratory
- Mold Lab
- Masonry Laboratory
- Hydraulic Installations Laboratory
- Painting Laboratory
- Building Materials Laboratory
- Soil Mechanics Laboratory

For this study, as mentioned in sub-item 2.1, only some of the available laboratories were used, due to the factors exposed therein and the limitation of the total number of researchers per advisor (only two). Consequently, the Masonry and Hydraulic Installations Laboratories were initially selected. Each one had the direct participation of a designated researcher, responsible for surveying the practical activities related to the study. This approach ensured continuous monitoring of the use of materials and equipment, as well as the generation of waste in each environment. The technical support was provided by the coordination of laboratories of the Civil Construction Area of CEFET-RJ, Maracanã Unit, which collaborated in the supervision of the activities and data collection for later analysis.

RESULTS

The results presented in this section come from the work conducted in two specific laboratories of the Civil Construction Course of CEFET-RJ, each supervised by a designated researcher. These researchers were responsible for monitoring and analyzing the use of materials in practical classes, proposing sustainable alternatives for waste reuse.

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The results detailed below present the main findings obtained in the Masonry and Hydraulic Installations Laboratories, where solutions for material reduction and reuse were tested.

MASONRY LABORATORY

In the Masonry Laboratory of the Civil Construction Course at CEFET-RJ, the experiments focused on the reuse of argalama, a mixture of clay, sand and water used in practical masonry classes. The research conducted by Pedro Aurélio Ferreira Rocha tested the feasibility of reusing the mortar after its initial use, since all the material was discarded after each class. Table 1 presents the test campaign carried out to verify the potential for reuse of the argalama.

Table 1 – Tests carried out to verify the reuse potential of the mortar

Essay	Procedures	Drying time
A1	Solid brick masonry wall sample laid with 1:2 trace mortar (sand/gravel)	2 days
A2	Solid brick masonry wall sample laid with 1:3 trace mortar (sand/gravel)	7 days
B1	Bucket with wet 1:2 trace mortar (sand/gravel)	2 days
B2	Bucket with wet 1:3 dash mortar (sand/gravel)	7 days

Source: Rocha and Tozatto (2023).

The tests were conducted with two different mixing compositions (1:2 and 1:3 ratios), and the experimental walls were dismantled after two and seven days. The evaluation included the workability of the dry and rehydrated mortar, as well as the ease of reapplication in new assemblies. Figures 1, 2 and 3 illustrate some moments of this campaign.

The results showed that, after the addition of water, the mortar could be successfully reused, presenting satisfactory characteristics for reuse in new classes. The tests with the 1:3 ratio demonstrated greater plasticity, which favored handling in subsequent activities, while the 1:2 ratio, although slightly less plastic, was also efficiently reused.

These experiments indicate a significant reduction in waste generation during practical classes. The analysis of the data suggests a potential reduction of up to 95% in masonry waste, since the practice of reuse can be applied in successive assemblies. This not only reduces environmental impact but also promotes a more conscious approach to the use of materials among students.

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Figure 1: Experimental walls built with 1:3 line mortar.

Source: Source: Rocha and Tozatto (2023).

Figure 2: Process of dismantling the wall after 7 days to reuse the argalama.

Source: Rocha and Tozatto (2023).

Figure 3 – Bucket containing argalama.

Source: Rocha and Tozatto (2023).

An additional advantage is the low cost of the technique, as it does not require significant additional materials, making its implementation feasible in an educational environment, especially in public institutions. The proposal to incorporate the reuse of mortar in pedagogical practices also serves to make students aware of the importance of sustainability in civil construction.

Although these results demonstrate promising potential for the reuse of argalama, it should be noted that the experiments were conducted under controlled laboratory conditions and for a limited number of reuse cycles. The long-term effects of repeated reuse were not evaluated in this study.

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LABORATORY OF HYDRAULIC INSTALLATIONS

At the Hydraulic Installations Laboratory, researcher Fernanda de Mesquita Araújo conducted a study focused on the reuse of PVC pipes, a material widely used in practical classes. The study aimed to find ways to reduce the waste generated during the assembly and disassembly of welded and threaded PVC hydraulic trajectories. Detailed analyses were carried out regarding the amount of material wasted in practical classes. Table 2 presents three of the six practical classes where there was greater waste generation.

Table 2 – Practices of the Technical Course in Buildings that generate greater amounts of waste.

Practice	Description
I	Execution of weldable PVC installation;
II	Cutting, squaring and threading in threaded PVC
III	Execution of a water installation with threaded PVC piping

Source: Tozatto and Araújo (2020).

Throughout the three practices carried out in a semester, an average waste of 15% to 20% of the pipes and fittings used was observed. Table 3 presents the materials and procedures used, and Figure 4 provides a perspective of the extension performed by the students in practices II and III.

Table 3 - Materials and procedures used in three of the practices carried out in the Hydraulic Installations Laboratory

Practice	Materials	Procedures
I	Weldable PVC pipe 20 or 25mm; Weldable connections (Tee and knee) 20 or 25 mm; water sandpaper; plastic adhesive.	Each student works with a 25 cm piece of pipe and welds a tee and a knee at each end.
II	Threaded PVC pipe 1/2" or 3/4"; Threaded connections (Tee and knee) 1/2" or 3/4"; Thread sealing tape.	Each student works with a 25 cm piece of tube and opens a thread, with the help of appropriate tools, at each end. Then it places two connections.
III	Threaded PVC pipe 1/2" and 3/4"; Assorted 1/2" or 3/4" threaded connections; Shower and registration; Thread sealing tape.	Based on a schematic of the extension provided, the student cuts, scans and opens threads to perform the proposed installation. It contemplates the heights of use of a shower, toilet, sink and register.

Source: Tozatto and Araújo (2020).

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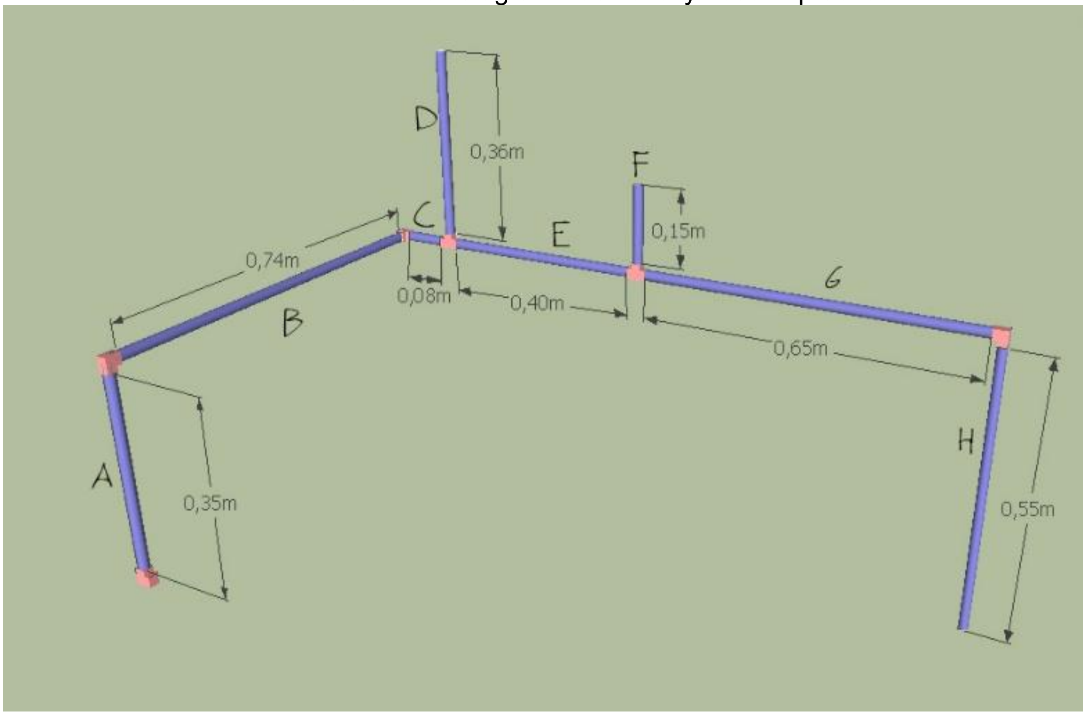
4: Threaded PVC branch diagram traditionally used in practice III.



Source: Tozatto and Araújo (2020).

This occurs mainly due to the lack of standardization in the cutting of tubes, the non-reuse of larger pieces and the destination of these pieces, at the end of the practices, as 'gifts' or souvenirs for students.

To promote changes in this way of teaching, simulations were carried out to optimize the lengths of the tubes and reduce material waste during cutting, welding and tapping practices. Figure 5 presents the perspective of the new extension proposal to be carried out by the students. Table 4 presents the new actions proposed to combat waste.

Table 4 – Proposed processes for optimizing the cutting of PVC pipes

Process 1	With the 3.0m pole already cut into pieces of 0.75m, each segment of 0.75m is divided into three parts of 0.25m. This generates 12 pieces of PVC pipe, distributed among the students. For better use, it is recommended that they do the practice of welding and threading their respective pieces of PVC pipe. If you want greater savings, you can work in pairs.
Process 2	After using the 12 tubes with 0.25m, the connections and the parts already threaded are removed, which generates 0.04m of waste, but the tube now with 0.20m (sawing the ends) can be used again.
Process 3	Procedure 2 is repeated in the 12 tubes with 0.20m, which generates 0.15m, and can still be reused.
Process 4	The same procedure present in the two previous processes is repeated in the 12 0.15m pipes, resulting in a 0.10m pipe, the latter being no longer reused, becoming solid waste.

Source: Tozatto and Araújo (2020).

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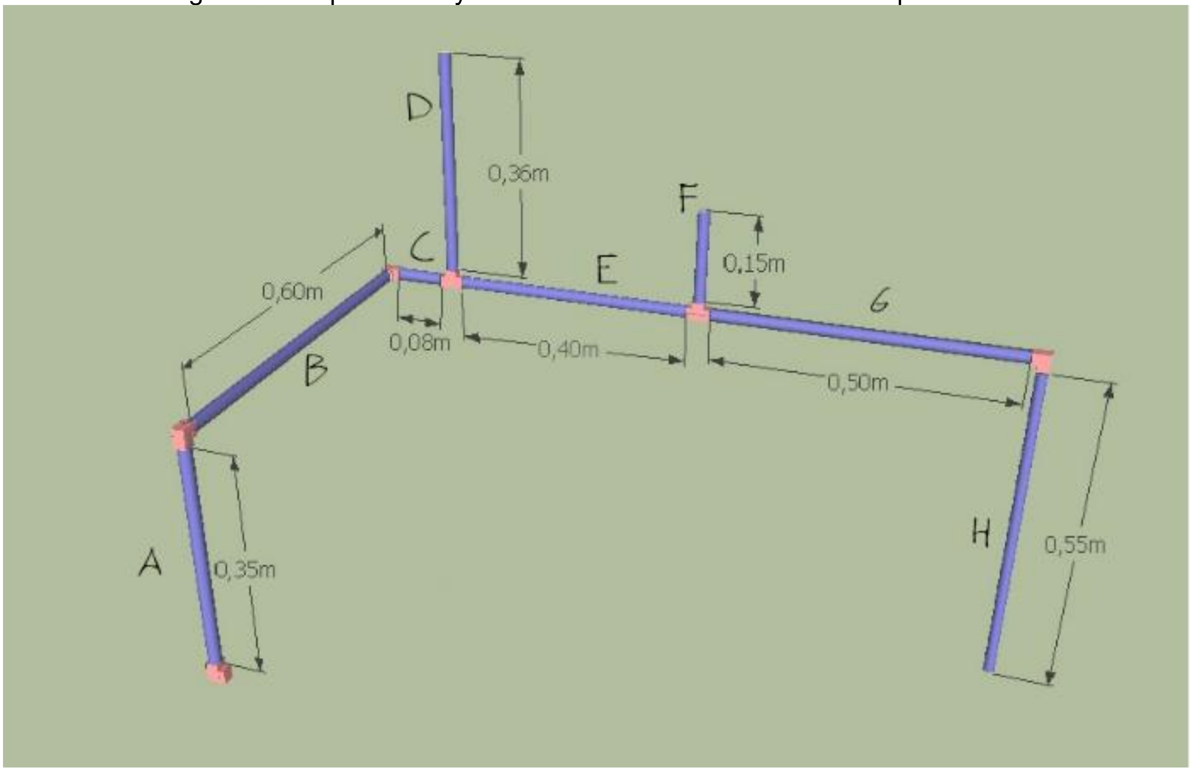
Figure 5 - Proposal for hydraulic installation to be executed in practice III.



Source: Tozatto and Araújo (2020).

After the experimental implementation of the new proposal, the results indicated that, through the standardization of the cut sizes of the tubes and the reuse of the tubes in subsequent practices, it was possible to reduce the consumption of new tubes by up to 66%. In addition, the reuse of smaller fittings and pipes proved to be a practical and sustainable solution, with significant resource savings over time.

The data also suggest that student awareness and the adoption of standardized practices, such as proper cutting and careful handling of pipes, can have a direct impact on waste reduction. The implementation of a simple reuse flow, as proposed in the study, enables the reuse of up to 80% of the tubes used during the academic semester.

The creation of clear standards for cutting and assembling PVC, combined with the promotion of reuse, also increases awareness of the life cycle of materials, an essential competence for future construction professionals.

It is important to recognize that these findings are based on a specific set of classes and groups of students during the study period. The generalization of these results to different educational contexts or longer periods may require further investigation.

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DISCUSSION

The results obtained in the Masonry and Hydraulic Installations Laboratories of CEFET-RJ demonstrated that the reuse of pedagogical waste, such as argalama, as well as PVC pipes and fittings, contributes directly to the saving of materials and the reduction of environmental impacts — even if not in very significant volumes. The study confirms the feasibility of integrating sustainable practices into the pedagogical environment, benefiting both the technical training of students and the development of critical environmental awareness.

For a more detailed understanding of the impacts of the proposed changes to more sustainable practices, the results obtained in the two pedagogical environments studied — the Masonry Laboratory and the Laboratory of Hydraulic Installations — will be addressed separately. Each presented specific challenges and solutions adapted to the nature of the waste generated and the materials reused.

MASONRY LABORATORY

In the Masonry Laboratory, the research conducted by researcher Pedro Aurélio Ferreira Rocha explored the reuse of argalama, a pedagogical mortar used in the practical classes of the Construction Technology discipline in the Technical Course of Buildings for more than 80 years. Although the exact origin or author of the mortar is unknown, its reuse was not considered within established laboratory practice—it was simply discarded.

In this context, it is important to emphasize that practical classes play a fundamental role in the training of building technicians, as they aim to contextualize the techniques used in construction technology. Unlike the training of bricklayers, which is characterized by the continuous manual repetition of techniques, the training of technicians seeks to integrate theory and practice in a broader and more conceptual way. In this sense, a single practical class allows the application and immediate experience of the theoretical concepts learned in the classroom (DEWEY, 1959; KOLB, 2014).

According to the Pedagogical Project of the Technical Course in Buildings (BRASIL, 2020b), the objective of the first masonry practice is to familiarize students with the types of masonry and the materials used in its construction. It consists of presenting the tools, their handling and use. As an integral part of this introduction, the materials used to build a masonry wall are presented, along with the theoretical concepts of mortar laying, its

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preparation and the execution of masonry using solid bricks. Equipment and tools used include 20-liter plastic buckets, trowels and plumb levels.

Pedro Aurélio's contribution focused on experimenting with different mixing ratios (1:2 and 1:3), monitoring drying times and evaluating the workability and plasticity of the rehydrated mortar for reuse purposes. The results indicated that both the 1:2 and 1:3 ratios allowed the effective reuse of the mixture, with the 1:3 ratio showing greater plasticity and facilitating handling. The reuse of the mortar through simple rehydration methods allowed its use in up to three consecutive cycles without compromising the strength or finish of the assembled structures.

Studies with cementitious mixtures corroborate these findings, which suggest that reuse in educational environments can reduce the use of new materials by up to 80%, creating an economically viable and environmentally responsible approach to the teaching of civil construction (SILVA et al., 2014). The implementation of sustainable practices in technical education can have long-term impacts, both in terms of saving resources, even if not in very significant volumes, and in fostering a culture of reuse among future professionals. Table 5 presents a comparison between the use of mortar and conventional mortar.

Table 5 – Comparison between mortar and conventional mortar.

Parameter	Mortar (Sand+Clay+Water)	Conventional Mortar (Cement + Sand + Water)
Cost	Reduced, uses simple and cheap materials	Higher, due to the use of cement
Application	Exclusively pedagogical, not used in construction sites	Used on construction sites and for practical simulations
Resistance	Does not offer structural strength	It has limited mechanical resistance
Sustainability	Sustainable, does not use cement	Increased environmental impact due to cement use
Purpose	Didactics, educational practice	Pedagogical and practical, used in real works

Source: Rocha and Tozatto (2023).

Cost analysis is one of the main factors in the selection of materials for civil construction, especially in educational and technical training environments, where the economic viability of practices needs to be considered. In this section, we compare the costs involved in the production of 1m³ of mortar and conventional mortar, using the SINAPI Table (CEF, 2024) as a reference for input prices.

Argalama, composed of clay, sand and water, has a significantly lower cost compared to conventional mortar, which is composed of cement, sand and water. The comparison of input costs reveals that, while conventional mortar uses six bags of cement per cubic meter, mortar replaces cement with clay, resulting in a substantial reduction in the final price.

Based on a fictitious conversion rate (1 USD = 5 BRL), the costs in US dollars (USD) are as follows:

- The production cost of $1m^3$ of mortar is approximately 22.3 USD.
- The production cost of $1m^3$ of conventional mortar is approximately 50.3 USD.

This significant difference in cost can be attributed mainly to the replacement of cement, a more expensive material, with clay, which is more affordable.

Additionally, the use of mortar does not require the same level of structural strength as conventional mortar, making it an effective and low-cost pedagogical solution for practices in technical laboratories, where the primary objective is the teaching of construction techniques, and not the execution of permanent structures.

In terms of economic impact, the use of mortar in pedagogical activities to contextualize the use of techniques and tools offers a more sustainable and accessible alternative, allowing educational institutions to reduce operating costs without compromising the quality of learning. In addition, the reduction in the use of cement helps to reduce environmental impacts, since cement production is one of the main contributors to CO_2 emissions in the construction industry.

LABORATORY OF HYDRAULIC INSTALLATIONS

In the Laboratory of Hydraulic Installations, a considerable loss of material was observed in the current practices due to the lack of compatibility between the design of the branch line and the size of the PVC pipes, the absence of standardized cuts and the discarding of all the work performed as a souvenir for the students. The research conducted by Fernanda de Mesquita Araujo aimed to optimize the use of PVC pipes to reduce waste.

The proposals for a new branch project, the introduction of cutting patterns and the reuse of smaller pipes and connections generated resource savings in practical classes, even if not in large volumes. Table 6 presents a comparison of waste generation in Practice I.

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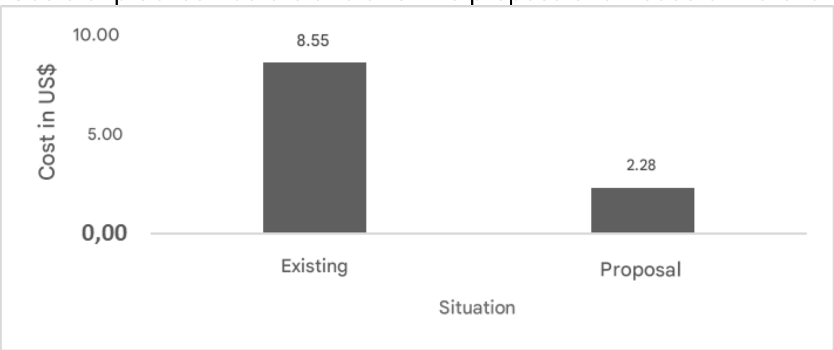
Table 6 – Waste generation every three classes of practice I.

Class	Existing situation	Proposed situation
1	3.00m	0m
2	3.00m	0.60m (12 x 0.05m)
3	3.00m	0.60m (12x 0.05m) + 1.20m (12x0.10m) = 1.80m
Total	9.00m	2.40m

Source: by the Author (2024).

It is observed that in a cycle of 3 classes, the 6-meter-long tube reaches the end of its usefulness when reused. Thus, the total waste generated is reduced by 73.33%. Figure 6 illustrates the comparison of costs for Practice I between the existing situation and the situation proposed from the study conducted by researcher Fernanda.

Figure 6 - Costs of practice I before and after the proposals for reuse of materials.



Source: by the Author (2024).

In addition to saving resources, the students of the experimental class that introduced this new methodology demonstrated greater awareness of the importance of sustainable practices in the use of materials. The process of standardization and reuse encouraged students to reflect on the waste of materials in real projects, preparing them to apply these practices in the job market.

Studies have shown similar results in optimizing the use of PVC pipes in construction projects, indicating a reduction of up to 60% in the materials used. This confirms that the standardization of cuts and the reuse of PVC pipes can lead to significant material savings in both educational and professional practices, reinforcing the importance of adopting these practices to reduce environmental impact. The research shows that technical education can be a starting point for implementing sustainable solutions that can be easily replicated in real construction contexts.

Despite the positive results demonstrated by the experimental practical class, a significant challenge persisted: the initial and continuous resistance of the instructors of the Construction Technology discipline to adopt practices of reuse of pipes. More than 15 years

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have passed since the surveys were conducted, and the situation remains unchanged; The original resistance still persists.

OPTIMIZATION OF PRACTICES, INTERNAL RESISTANCE, PEDAGOGICAL IMPACT AND ALIGNMENT WITH SUSTAINABILITY

Despite the effectiveness of the sustainable practices implemented in the laboratories, internal resistance to the adoption of these practices remains a reality. In many cases, this resistance is attributed to the reliance on traditional teaching methods and the lack of institutional incentives to implement new approaches. Even in an educational setting, where innovation should be encouraged, there is often a reluctance to abandon established methods, which can slow down the transition to more sustainable practices. Overcoming these barriers depends on institutional commitment and coordinated efforts to integrate sustainability into the curriculum in an ongoing and systematic manner.

The attempt to introduce these sustainable practices in laboratory classes provided students, even if briefly, with a critical view of the life cycle of construction materials and awareness of the importance of sustainability in the sector. According to the literature, exposing students to material reuse practices during their technical training significantly increases their ability to apply these concepts in future projects (SIVAPALAN and CLIFFORD, 2019).

These practices are also aligned with the Sustainable Development Goals (SDGs) of the 2030 Agenda. In particular, SDG 4, which promotes quality technical education, and SDG 12, which encourages sustainable consumption and production, resonate with CEFET-RJ initiatives. The reuse of materials in laboratories contributes to the training of more conscious professionals, trained to implement sustainable practices in their areas of expertise. Simultaneously, the institution reaffirms its commitment to sustainability and the development of an environmentally responsible culture among its students.

The integration of sustainability into the technical curriculum is in line with the National Policy on Environmental Education, Law 9.795 (BRASIL, 1999), which encourages the inclusion of sustainable practices in educational environments. The research conducted at CEFET-RJ exemplifies how environmental education can be effectively incorporated into technical education, training professionals committed to sustainability. The attempt at an innovative pedagogical approach applied in the Masonry and Hydraulic Installations laboratories demonstrates that it is possible to harmonize theory and practice in order to

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prepare students for environmental challenges and the application of sustainable solutions in their future professional performance.

The results obtained in this study are consistent with previous research that demonstrated that reusing waste in small-scale projects reduced total material costs by 25%. The adoption of material reuse practices, such as the reuse of mortar, can generate water and energy savings, contributing to the efficiency of production processes.

Although the study focused on the reuse of materials in an educational context, the implications of these practices go beyond the classroom. In the future, these methodologies could be easily adapted to small-scale projects and in the modeling of larger construction projects. The adoption of simple solutions, such as standardizing cuts and reusing waste, has the potential to reduce the environmental impact of projects of various sizes.

STUDY LIMITATIONS

This study, which demonstrates the potential of sustainable practices in the teaching of civil construction, was conducted in a controlled environment at CEFET-RJ. This specificity may limit the direct applicability of the results to other educational or cultural contexts.

The one-year duration allowed for a comprehensive analysis, but it may not have been sufficient to fully capture the long-term effects of the practices implemented. A more extensive evaluation would be necessary to determine the continued effectiveness and durability of the proposed solutions.

The reluctance observed among some faculty members to adopt new methodologies highlights potential challenges for large-scale implementation. This resistance highlights the complexity of modifying methods established within the academic environment, even when evident benefits are present.

This article focuses on the initial results of the Research Project 'Reuse of Civil Construction Waste Applied to the Pedagogical Environment', specifically in the Masonry and Hydraulic Installations laboratories. It is important to emphasize that these represent the initial stages of a broader investigation, which later covered other practical environments of the Civil Construction course.

The insights gained in the Masonry and Plumbing Installation laboratories provide a solid basis for understanding sustainable practices in these key areas of technical training. Although this study does not cover the other laboratory settings subsequently analyzed, it establishes a crucial starting point for future explorations. The findings presented show the importance and potential for expansion of these sustainable initiatives to other aspects of civil construction education.

INTERNATIONAL PERSPECTIVE ON SUSTAINABLE PRACTICES IN TECHNICAL EDUCATION

The initiatives implemented at CEFET-RJ reflect a global trend in technical education for civil construction. In several countries, educational institutions have sought to integrate sustainable practices into their curricula, although with different approaches.

In Germany, for example, the dual education system combines theoretical learning with practical experience in companies, allowing students to apply sustainability concepts directly in the workplace. A study conducted at the Technical University of Munich revealed that this approach resulted in a 30% reduction in material waste in construction projects involving students (ALAM BHUIYAN and HAMMAD, 2024).

In Australia, the Green Skills Agreement has established national guidelines for incorporating sustainability skills into technical education curricula (UNITED NATIONS, 2024).

In the Asian context, Singapore stands out for the implementation of the 'SkillsFuture' program, which emphasizes continuing education in sustainable practices for construction professionals (LIM et al., 2024).

These international experiences corroborate the importance of the initiatives developed at CEFET-RJ, while pointing out potential paths for expanding and improving sustainable practices in technical education for civil construction in Brazil.

CONCLUSION

The results of this research, particularly in the Masonry and Hydraulic Installation Laboratories, confirm the significant potential of implementing sustainable practices in technical education for civil construction. The reuse of materials, such as mortar and PVC pipes, resulted in savings, albeit of reduced magnitude, in the academic laboratory environment. For example, the consumption of new materials was avoided and waste disposal was drastically reduced, demonstrating the viability of these solutions in the educational context.

These practices not only generate economic and environmental benefits, but also play a crucial role in training future professionals who are more aware and able to implement sustainable solutions. By integrating sustainability concepts into technical education, educational institutions prepare their students to face global challenges in the construction sector. This approach aligns directly with the Sustainable Development Goals (SDGs), especially SDG 4 (Quality Education) and SDG 12 (Responsible Consumption and Production) (UNITED NATIONS, 1992).

Based on the results and analysis of CEFET-RJ practices, the following recommendations can be proposed to strengthen and expand the adoption of sustainable practices in technical education for civil construction:

1. Curricular Integration: Deepen the incorporation of sustainable practices in the Pedagogical Course Projects (PPC) in the area of civil construction, using the experience of CEFET-RJ as a model for other institutions.
2. Expansion of Sustainable Initiatives: Extend programs such as the Environmental Agenda in Public Administration (A3P), encouraging other technical education institutions to participate and develop innovative sustainability projects.
3. Integrated Training: Develop training programs that integrate sustainable practices with innovative teaching methodologies, taking advantage of CEFET-RJ's experience in awareness courses and lectures, and extending the focus to specific teacher training.
4. Academia-Industry Partnerships: Foster collaborations between educational institutions and companies in the construction sector for the practical application of sustainable concepts, inspired by CEFET-RJ's successful sustainability initiatives.

However, critical analysis of the data reveals that resistance to the implementation of these practices remains an obstacle. Institutional barriers, such as lack of incentives and teacher evaluations, dependence on traditional teaching methods, and inadequate financial resources, must be overcome to ensure the implementation and scalability of these solutions. While the study employed accessible techniques and tools, it is important for other institutions to take a continuous approach to pedagogical improvement and innovation.

The interdisciplinary potential of these sustainable practices should not be overlooked. They can be integrated with several other disciplines, such as Chemistry and Biology, enriching the training of students and preparing them to address the complex sustainability challenges they will face in their professional careers.

Future studies could explore the application of these practices in different areas of civil construction, such as the use of concrete, forms, electrical materials and sustainable paints, as well as investigate the replicability of these methodologies in institutions with more limited infrastructure. It would also be valuable to monitor the long-term impacts of these practices on student education, if resistance to their implementation can be overcome, assessing how these experiences influence their decisions in the labor market.

The introduction of emerging technologies, such as smart sensors, although not essential in the current context, could enhance the positive impact of these practices, allowing for more efficient monitoring and improving the reuse of materials. This would also bring the educational environment closer to the innovations applicable in the construction industry, preparing students for a more sustainable professional future.

In conclusion, this study demonstrates the feasibility and importance of integrating sustainable practices in technical education for civil construction. The results obtained at CEFET-RJ indicate that these practices can be implemented in educational environments, contributing to the training of professionals who are more aware of environmental issues. The application of these methodologies in other educational institutions has the potential to promote significant advances in the sustainability of the civil construction sector.

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