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MATHEMATICS EDUCATION AND SUSTAINABILITY: INTERDISCIPLINARY PRACTICES IN SOLID WASTE MANAGEMENT AND SUSTAINABLE PRODUCTION

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ABSTRACT
This article presents the development and analysis of an activity linked to the project "Development of Didactic Materials for the Virtual Mathematics Laboratory of the Iguaçu University". The main objective was to integrate Mathematics and sustainability, exploring solid waste management and food production with the use of leachate as a natural fertilizer. The activity was structured in interdisciplinary tasks that included the collection and categorization of waste, elaboration of mathematical problems and cultivation of coriander using fertilizer produced. Applying concepts such as proportionality, percentage and statistics, the undergraduate student contextualized Mathematics in real practices, aligning herself with the theories of Critical Mathematics Education and Ethnomathematics. Results indicate that the approach promoted reflection on sustainability and consumption habits, highlighting the relevance of Mathematics as a tool for awareness and social transformation. Despite limitations related to the representativeness of the data and the long-term analysis, the project demonstrated strong pedagogical potential to engage students and teachers in contemporary environmental issues.

Keywords: Critical Mathematics Education. Sustainability. Solid Waste. Ethnomathematics. Interdisciplinary Practices.

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INTRODUCTION

Mathematics plays a crucial role in understanding and solving contemporary challenges that directly affect society and the environment, such as solid waste management and the promotion of sustainable practices. In the educational context, this discipline transcends its technical application, assuming an interdisciplinary role that connects it to social and environmental issues. By addressing topics such as sustainability and solid waste, Mathematics acquires a transformative character, providing students with tools to interpret data, design scenarios and propose evidence-based solutions.

This experience report describes the development of an activity linked to the research project entitled *"Development of Didactic Materials for the Virtual Mathematics Laboratory of the Iguaçu University",* conducted within the scope of the Distance Learning Scientific Initiation Program of the Iguaçu University – UNIG, contemplated by the 2023.2 notice. The main objective of the project is to integrate Mathematics with the theme of sustainability, focusing on the management of solid waste, based on the elaboration of didactic materials that contribute to the critical and contextualized teaching of this discipline.

The reported activity is part of a context where Mathematics Education is increasingly called upon to collaborate with global challenges, such as those described in the Sustainable Development Goals (SDGs) of the United Nations. Issues such as the growing production of solid waste, which according to the UN (2021) will exceed 3 billion tons per year by 2050, demand sustainable solutions that integrate different areas of knowledge. Mathematics, with its ability to model scenarios and interpret complex data, is essential to foster a holistic understanding of these problems.

The pedagogical product developed, to be detailed in this report, addresses mathematical concepts associated with sustainability, such as calculations of recycling rates, statistical projections on waste generation and modeling of selective collection systems. The proposal aims not only to reinforce mathematical learning, but also to engage students in critical discussions about their role in society and the environment. This approach is aligned with theories such as Ole Skovsmose's Critical Mathematics Education, which proposes a teaching of Mathematics focused on social action, and Ubiratan D'Ambrosio's Ethnomathematics, which values the cultural and social contextualization of mathematical knowledge.

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In this article, the theoretical and methodological foundations that supported the activity, the processes of development of the didactic material and the results obtained will be discussed. From this experience, it seeks to contribute to the debate on the relevance of integrating Mathematics and sustainability in teaching, highlighting the potential of Mathematics Education to form critical and responsible citizens. The main objective of this text is to report the experience developed and present reflections on how contextualized pedagogical practices can expand the reach and applicability of Mathematics teaching, connecting it to real and urgent problems.

MATHEMATICS AND SUSTAINABILITY: NECESSARY CONNECTIONS

Critical Mathematics Education, proposed by Ole Skovsmose (2001), redefines mathematics as a field of action that goes beyond the limits of the traditional classroom, positioning it as an indispensable tool for social action. Rather than being seen only as an abstract discipline, mathematics is presented as a means for individuals to understand the structures and dynamics that shape society and thus tackle contemporary problems in a reasoned way. In the context of sustainability, this perspective transforms mathematics into a mediator in the interpretation of phenomena such as excessive waste production, inequalities in access to natural resources, and the ecological consequences of unbridled consumption.

Sustainability, as a global concept, requires an interdisciplinary approach that promotes a holistic understanding of environmental challenges. Mathematics, in this sense, offers rigorous methods for analyzing, modeling, and predicting complex scenarios. For example, the principles of statistics and probability can be utilized to evaluate patterns of waste consumption and production, while algebra and calculus assist in the creation of models that project the impact of recycling or composting policies over time. Skovsmose emphasizes that, by relating these concepts to real situations, educators make teaching more meaningful, allowing students to realize the relevance of mathematics in their daily lives and in collective decisions for a sustainable future.

In parallel, Ubiratan D'Ambrosio (2002), with his approach to Ethnomathematics, proposes a complementary view by highlighting that mathematical knowledge is not homogeneous or universal, but is intrinsically linked to cultural and historical contexts. This perspective is especially relevant in solid waste management, where traditional practices of local communities can offer sustainable and context-adapted solutions, such as artisanal

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composting techniques or creative reuse of materials. Ethnomathematics values this local knowledge, promoting a dialogue between scientific and popular knowledge, allowing these systems to coexist and mutually enrich each other.

This interaction between mathematics and sustainability gains strength when applied to the analysis of environmental issues. Recent studies highlight how pedagogical activities that integrate mathematics with environmental problems have the potential to generate awareness and promote significant changes in habits. For example, ecological footprint calculations, often used in educational campaigns, help individuals measure the impact of their actions on the environment, encouraging more sustainable choices. Likewise, the analysis of data on waste generation and recycling, involving mathematical concepts such as percentages, means, and standard deviations, helps communities evaluate their effectiveness in waste management and plan continuous improvement strategies.

Mathematical modeling is another powerful resource for connecting mathematics and sustainability. This technique allows you to simulate hypothetical scenarios, such as the impact of implementing plastic waste reduction policies or increasing the efficiency of selective collection routes. When used in the classroom, these practices become opportunities for students to develop analytical skills and become active agents in the search for environmental solutions.

When addressing the relationship between mathematics and sustainability, it is essential to also consider teacher training. Studies show that educators with adequate training to integrate environmental and mathematical themes are more effective in conducting interdisciplinary activities and engaging students in global issues. Initiatives such as continuing education programs for teachers and partnerships with institutions that promote education for sustainable development can enhance these connections.

In short, the intersection between mathematics and sustainability represents a unique opportunity to align the teaching of this discipline with the demands of the twenty-first century. Through critical approaches, such as Skovsmose's Critical Mathematics Education and D'Ambrosio's Ethnomathematics, and the use of practical tools such as mathematical modeling and data analysis, it is possible to prepare conscious and engaged citizens. Thus, mathematics is no longer just an academic abstraction and becomes a powerful ally in building a sustainable future.

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SOLID WASTE: CHALLENGES AND OPPORTUNITIES FOR MATHEMATICS EDUCATION

Solid waste management is among the most critical challenges of our time, reflecting the consequences of unsustainable consumption patterns and ineffective management. According to UN data (2021), the global production of solid waste, which currently exceeds 2 billion tons per year, could exceed 3 billion tons by 2050 if significant changes in production and disposal models are not adopted. This problem, which involves environmental, economic and social impacts, demands an integrated and systemic approach to the search for solutions. In this scenario, Mathematics Education emerges as a powerful tool to prepare citizens capable of understanding and facing these challenges through critical analysis, strategy formulation and reasoned decision-making.

Mathematics offers essential resources to address the quantitative and qualitative dimensions of solid waste. Through concepts such as statistics, algebra, geometry, and mathematical modeling, it is possible to interpret data, predict trends, and propose innovative solutions. For example, statistical analysis of waste generation patterns can reveal regional disparities, identify sectors that contribute most to pollution, and guide public policies towards more efficient management. Mathematical modeling, in turn, allows simulating future scenarios, considering variables such as population growth, urban expansion, and implementation of recycling policies, which can be applied directly in the classroom to foster learning based on real problems.

CHALLENGES IN SOLID WASTE MANAGEMENT AND EDUCATIONAL POSSIBILITIES

Among the most evident challenges is the lack of awareness about the impact of waste on the environment. Data from environmental organizations indicate that less than 20% of global waste is recycled, while the rest is disposed of inappropriately, contributing to the contamination of soils, rivers and oceans. Mathematics Education, by promoting the critical analysis of real data, can engage students in discussions about recycling, composting and waste reduction. Concepts such as fractions, proportions, and percentages can be applied to calculate recycling rates or the impact of adopting sustainable practices on specific communities.

Another challenging aspect is the logistics of collecting and treating solid waste. In urban areas, where waste generation is more intense, the optimization of routes for selective collection is a relevant problem that can be explored through mathematics.

Students can be encouraged to apply geometry and graph theory to develop solutions that minimize costs, reduce fossil fuel consumption, and improve the efficiency of collection systems. Such activities not only integrate different areas of mathematics, but also show students how mathematical knowledge can be used to solve concrete problems in their communities.

MATHEMATICS AS A BRIDGE TO SUSTAINABLE SOLUTIONS

Mathematics Education also plays a crucial role in projecting the impact of different solid waste management scenarios. For example, students can work with long-term calculations to evaluate the effect of implementing composting programs, considering variables such as the volume of organic waste generated and the time required for decomposition. These exercises can be associated with studies on the environmental benefits of composting, such as reducing greenhouse gas emissions and enriching the soil.

International initiatives, such as the *Mathematics for Planet Earth* program , offer practical and inspiring models for integrating environmental problems into mathematics education. This program proposes activities based on real data, such as the analysis of plastic waste in the oceans, calculations of carbon emissions associated with waste management, and estimates of the impact of changes in consumption habits. These initiatives have shown that mathematics can be a transformative tool, not only for learning, but also for building a critical and sustainable mindset.

PEDAGOGICAL PROPOSALS AND INTERDISCIPLINARITY

Interdisciplinarity is an essential approach to Mathematics Education in the context of solid waste. Projects that combine mathematics, geography, biology, and environmental education offer students a comprehensive overview of the challenges of sustainability. For example, a school project may involve measuring and classifying the waste generated by the school itself, using mathematical concepts to create graphs and tables that analyze the environmental impact of improper disposal. These activities allow students to become protagonists of the learning process, applying mathematical knowledge to identify problems and propose viable solutions.

In addition, the use of technology can enhance teaching and learning. Digital tools, such as data analysis software and mathematical modeling simulators, allow students to manipulate complex information in a visual and interactive way. These platforms also

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facilitate the integration of global data on solid waste, encouraging students to think about solutions that go beyond their local realities.

Solid waste management is both an urgent challenge and an educational opportunity to promote a Mathematics Education that is more connected to global issues. Through pedagogical approaches that integrate theory and practice, it is possible to transform environmental problems into rich contexts for the teaching of mathematics. This connection contributes to the development of analytical skills, creativity and critical sense, indispensable characteristics for the construction of a more sustainable society. By uniting mathematics and sustainability, schools can form citizens who understand the complexity of contemporary challenges and become active agents in the search for solutions.

DESCRIBING THE RESEARCH ACTIVITY OF THE PROJECT "DEVELOPMENT OF DIDACTIC MATERIALS FOR THE VIRTUAL MATHEMATICS LABORATORY OF THE IGUAÇU UNIVERSITY"

The activity entitled "Training of Educators for Environmental Awareness: Solid Waste Management and Practical Mathematical Applications" is part of the research project "Development of Didactic Materials for the Virtual Mathematics Laboratory of the Iguaçu University". This initiative seeks to align the teaching of Mathematics with sustainability issues, with a focus on solid waste management. The main objective of the activity was to promote practical and quantitative environmental awareness in future educators. Through the collection, categorization, weighing and analysis of solid waste, as well as the creation of didactic and practical activities related to composting and cultivation, participants were encouraged to apply mathematical concepts in real situations. This approach aimed to deepen the understanding of sustainable waste management and environmental responsibility in everyday life, highlighting the connection between Mathematics and real-world problems (UNIG, 2023).

GENERAL DESCRIPTION OF THE ACTIVITY AND ITS PEDAGOGICAL OBJECTIVES

The activity was structured in six interconnected tasks, designed to explore the intersection between Mathematics, sustainability and pedagogical practices. An innovative aspect of the proposal was the fact that the licentiate student should perform all the tasks in her own home, using the garbage generated by her family on a daily basis. This practical approach sought to involve the participant directly with the theme, showing how

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Mathematics can be integrated into the analysis and resolution of concrete problems, while promoting environmental awareness.

The central pedagogical objective was to create didactic material that could be replicated in school contexts, promoting the initial training of Mathematics teachers with a focus on interdisciplinarity and the practical application of mathematical concepts. Thus, in addition to learning how to collect, organize and interpret data related to waste management, the licentiate student was challenged to reflect on how these practices could be adapted to the teaching of children and adolescents.

STAGES OF THE ACTIVITY AND RESULTS ACHIEVED

The activity was divided into six specific tasks, which incorporated different aspects of waste management and its mathematical applications:

The first task consisted of storing and categorizing the domestic waste produced in the licentiate's home for three consecutive days. The waste was divided into categories such as organic, recyclable (paper, plastic, glass, metal), tailings and hazardous materials. The objective of this stage was to sensitize the participant about the amount and diversity of waste generated in daily life, in addition to introducing mathematical concepts such as classification and organization of data.

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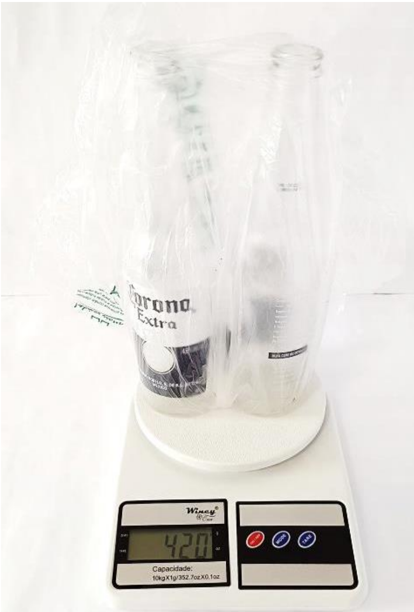
Table 1: Garbage produced, separated and weighed in the period of three days.

Task 1: Store all solid waste in your home for three full days. Separate them into plastic bags according to the following category: Glass Materials, Plastic Materials, Organic Materials, Paper Materials, Metal and Aluminum Materials, and Tetra Pack Materials. Examples of solid waste that will be collected: milk cartons, eggs, plastic bottles, plastic packaging, among others. For this task, we will dispose of solid waste from personal use, such as toilet paper, for example, as well as cooked organic materials, for example, meat and vegetables. Thus, in relation to organic waste, only fruit, vegetable and egg peels should be collected, as well as seeds.



Source: Prepared by the author (2023)

In the second task, the licentiate student weighed each category of waste using a domestic scale. The results were recorded in a table, including information on the weight of each category per day and the average daily waste production. This stage highlighted the practical application of concepts such as arithmetic mean and comparative analysis, connecting mathematical learning to an everyday activity.

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Chart 2: Table of Data Notes of the garbage collected.

Task 2: Now, using a precision scale, weigh all the solid waste produced during these three days and write it down in the table below:

SOLID WASTE	WT (gram)
Glass Materials	420g
Plastic Materials	319g
Organic Materials	490g
Paper Materials	42g
Metal and Aluminum Materials	34g
Tetra Pack Materials	130g
TOTAL	1.435g

Source: Prepared by the author (2023)

Based on the data presented in Task 2, which record the weights of different types of solid waste collected by the licentiate student in her residence over three days, the next stage consisted of the elaboration of interdisciplinary mathematical problems. These problems address elementary and high school content, integrating Mathematics, sustainability and solid waste management. The proposal aimed not only to apply mathematical concepts such as proportionality, percentage, statistics, and the rule of three, but also to stimulate critical reflection on consumption habits, disposal, and sustainable practices.

The activities were carefully planned to promote a practical and contextualized approach, which, according to Skovsmose (2001), is essential to connect mathematical learning to real issues and foster Critical Mathematics Education. In addition, this approach is in line with the assumptions of the BNCC, which highlights the importance of interdisciplinarity and contextualization in teaching.

Chart 3: Example of a Problem prepared by the author from activities 2 and 3.

Task 3: From the table above, develop four didactic activities involving some Mathematics content from the final grades of Elementary School and/or High School.

Source: Prepared by the author (2023)

Next, the proposed problems, their resolutions and a discussion about their pedagogical implications are described.

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Problem 1: Proportionality and comparative analysis

Statement: Using the data from Task 2, calculate the proportion between organic, recyclable (plastic, glass, metal, Tetra Pak) and non-recyclable (paper) waste. Then, analyze which category has the greatest representativeness in relation to the total waste generated and discuss how it would be possible to reduce the production of non-recyclable waste.

Resolution:

- Organic waste: 490g
- Recyclable waste: 420g (glass) + 319g (plastic) + 34g (metal and aluminium) + 130g (Tetra Pak) = 903g
- Non-recyclable waste (paper): 42g
- Total waste: 1.435g

Proportion:

- Organic/Total: $\frac{490}{1435} \cong 0{,}34\ (34\%)$
- Recyclables/Total: $\frac{903}{1435} \cong 0{,}63\ (63\%)$
- Non-recyclable/total: $\frac{42}{1435} \cong 0{,}03\ (3\%)$

Pedagogical discussion

This problem allows us to explore the concept of proportion in an applied way, connecting Mathematics to the critical analysis of waste generation. From the results, students can discuss how to increase recycling (already significant, 63%) and strategies to reduce organic waste (34%), for example, through composting. According to D'Ambrosio (2002), contextualized activities such as this promote an Ethnomathematical Mathematics Education, valuing local knowledge and connecting it to global issues.

Problem 2: Percentage and composition of garbage

Statement: Based on the data in the table, determine the percentage that each type of waste represents in relation to the total collected. After calculating, discuss how these percentages can be used to plan reduce, recycle, and compost strategies.

Resolution:

- Percentage of waste:
  - Glass: $\frac{420}{1435} \text{X } 100 \cong 29{,}3\%$

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- Plastic: $\frac{319}{1435}$ X $100 \cong 22{,}2\%$
- Organic: $\frac{490}{1435}$ X $100 \cong 34{,}1\%$
- Paper: $\frac{42}{1435}$ X $100 \cong 2{,}9\%$
- Metal and Aluminum: $\frac{34}{1435}$ X $100 \cong 2{,}4\%$
- Tetra Pak: $\frac{130}{1435}$ X $100 \cong 9{,}1\%$

Pedagogical discussion

By calculating percentages, students learn to relate the absolute numbers of waste to their representativeness in the total. This quantitative analysis provides a basis for discussing management strategies, such as encouraging the composting of organic waste (34.1%) and the reuse of recyclable materials such as glass (29.3%) and plastic (22.2%). According to UN studies (2021), understanding the composition of garbage is essential to implement sustainable policies, a topic that can be explored in the classroom to connect Mathematics to citizenship.

Problem 3: Statistics and variation in waste production

Statement: Use the data provided to calculate the mean, median, and standard deviation of waste weights by category. Discuss how these concepts can be used to evaluate patterns in waste production and propose improvements in disposal habits.

Resolution:

- Weights: 420g (glass), 319g (plastic), 490g (organic), 42g (paper), 34g (metal), 130g (Tetra Pak).
- Average: $\frac{420+319+490+42+34+130}{6} = \frac{1435}{6} \cong 239{,}17\text{g}$
- Median: Ordering the values (34, 42, 130, 319, 420, 490), the median is the average of the two central values: $\frac{130+319}{2} = \frac{449}{2} \cong 224{,}5\text{g}$
- Standard deviation calculation:

1. Average: 239.17g
2. Squared deviations:

$(420 - 239,17)^2 \approx 32.770$, $(319 - 239,17)^2 \approx 6.366$, etc.

3. Variance = $\frac{\Sigma(x-\bar{x})^2}{n}$

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4. Standard Deviation = $\sqrt{\text{variância}}$

Pedagogical discussion

This problem reinforces fundamental concepts of statistics and their practical application. In addition, students can reflect on how the variation in waste production reflects consumption and disposal habits, encouraging behavioral changes. According to Skovsmose (2001), the use of real data in the classroom makes learning more meaningful and connected to the students' reality.

Problem 4: Rule of Three and Decomposition Time

Statement: Knowing that 1 kg of plastic takes, on average, 450 years to decompose, calculate how long it would take for the decomposition of all the plastic collected (319g). Next, discuss the environmental impacts of difficult-to-decompose materials and the importance of recycling.

Resolution:

- Rule of three:

1000g $\rightarrow 450 \text{ anos}$

319g $\rightarrow x$

$$x = \frac{319\ X\ 450}{1000} \cong 143{,}55 \text{ anos}$$

Pedagogical discussion

This problem connects Mathematics to the time of waste decomposition, helping students to visualize the environmental impact of improperly discarded materials. In addition, the activity promotes discussions on recycling as a solution to reduce this impact.

These problems illustrate how Mathematics can be integrated with sustainability to promote more contextualized and meaningful teaching. Activities like these not only reinforce mathematical skills, but also stimulate students' critical awareness and engagement with real problems. The interdisciplinary and reflective approach, based on theories of Critical Mathematics Education and Ethnomathematics, demonstrates the transformative potential of Mathematics as a tool for analysis and action in facing global challenges.

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LEACHATE PRODUCTION FROM ORGANIC WASTE: SUSTAINABLE PRACTICE AND PEDAGOGICAL REFLECTIONS

After the elaboration and resolution of the mathematical problems based on the data of the solid waste collected, the licentiate student was challenged to apply the theoretical and practical concepts in a new context: the production of leachate from the organic waste generated in the three consecutive days of collection. This stage of the project aimed not only to deepen knowledge about sustainability and waste reuse, but also to demonstrate the feasibility of sustainable practices in everyday life. In addition, the activity sought to integrate Mathematics, Environmental Education and practical experimentation, promoting an interdisciplinary and meaningful approach to teacher training.

Preparation of the composter with PET bottles

The proposed task guided the assembly of a homemade composter using PET bottles with a capacity of 2.5 liters. The undergraduate student followed the instructions presented in recommended teaching materials and videos, which highlighted the use of organic waste combined with dry material, such as leaves, sawdust or shredded paper, to ensure the balance between humidity and aeration in decomposition.

Stages of compost assembly

1. Preparation of PET Bottles:
   - Two 2.5-liter PET bottles were used. The licentiate student cut one of the bottles to create an upper opening and used its inverted base as a reservoir to collect the leachate. The other bottle was prepared with a small hole in the cap to allow the liquid produced to drain into the reservoir.
2. Assembly of the Waste Layers:
   - The 490g of organic waste collected were carefully arranged in the bottle in alternating layers with dry material. This technique was used to avoid excess moisture and promote homogeneous decomposition of the waste.
   - Examples of waste used: fruit and vegetable peels, food scraps and coffee grounds.
   - Dry material added: dry leaves and shredded paper.
3. Sealing and Monitoring of the Process:

- After assembling the layers, the composter was sealed and positioned in an airy place. During the follow-up, the licentiate student recorded the changes in decomposition and collected the leachate produced on the 21st, 31st and 44th, as illustrated in the attached photos.

Observations and leachate collection

The production of leachate was monitored over several weeks. Visual records show the collected liquid in three main steps:

- 21st day: Small amount of leachate produced, evidencing the beginning of the decomposition process.
- 31st day: Greater volume of leachate collected, indicating more advanced decomposition.
- 44th day: Production stabilized, with the slurry already accumulated at the base of the bottle, ready to be diluted and used as fertilizer.

The collection was carried out carefully to avoid waste and ensure that the liquid retained its natural properties.

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Table 4: Slurry production.

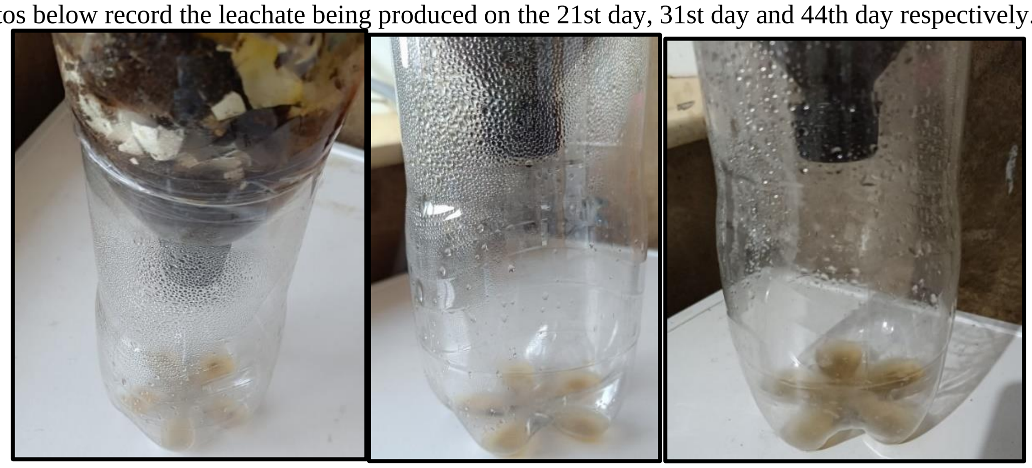
Task 4: With the organic waste, you must assemble a homemade composter in PET bottles (2.5 liters or 3 liters) for the production of organic fertilizer (leachate). To do this, follow the videos and texts indicated below.

guia_pratico_meio_ambiente.pdf (sabesp.com.br)
https://ainfo.cnptia.embrapa.br/digital/bitstream/item/141773/1/Doc-203.pdf
https://www.youtube.com/watch?v=4UyAXDanBDw
https://www.youtube.com/watch?v=g8vFRYdyuME
https://www.youtube.com/watch?v=kEj2IRGvBo0
UNBELIEVABLE CARROT PRODUCTION IN THE PET BOTTLE (youtube.com) - https://www.youtube.com/watch?v=YATv37eqJZA

To assemble the composter, I used two 2.5L pet bottles.

After that I added the organic waste. According to the information I collected, the ideal is to put one measure of soil, for every two measures of organic compounds. I used the smaller pet base as a measure, which in the end served as a lid for my composter.

The photos below record the leachate being produced on the 21st day, 31st day and 44th day respectively.



Source: Prepared by the author (2023)

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Mathematical calculations related to the production process

The activity also included carrying out mathematical calculations to analyze the results of decomposition and evaluate the efficiency of leachate production in relation to the initial weight of organic waste.

- Percentage of slurry produced in relation to the initial weight of the waste:
  - Initial weight of the waste: 490g.
  - Volume of leachate collected (44th day): approximately 200ml (estimated).
  - Percentage: $\frac{200}{490} X\ 100 \cong 40{,}8\%$

This calculation showed that about 40% of the weight of organic waste was converted into liquid during the decomposition process.

- Production Projection for Greater Volume of Waste:
  - If 1kg of organic waste were processed, what would be the expected volume of leachate produced?

Resolution:

- Rule of three:

490g $\rightarrow 200\ \mathrm{ml}$

1000g $\rightarrow x$

$$x = \frac{1000\ X\ 200}{490} \cong 408\ \mathrm{ml}$$

This projection helps to understand the scalability of the process for different amounts of waste, connecting Mathematics and sustainable practices.

Pedagogical reflections and environmental impact

The production of leachate highlighted the importance of sustainable practices in the management of organic waste. During her reflection, the licentiate student discussed how leachate, when diluted in water, can be used as a natural fertilizer, reducing dependence on chemicals in agriculture and in the care of domestic plants. In addition, she explored the positive impact of composting on the diversion of organic waste from landfills, reducing the emission of greenhouse gases, such as methane.

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This activity also offered a unique opportunity to integrate mathematical knowledge into the environmental context, aligning with the perspectives of Critical Mathematics Education (Skovsmose, 2001) and Ethnomathematics (D'Ambrosio, 2002). By connecting concepts of proportion, percentage and data analysis to the leachate production process, the activity reinforced the idea that Mathematics is not just an abstract discipline, but an essential tool for understanding and solving real problems.

The production of leachate was an essential stage in the development of the project, as it united practice and theory, promoting an interdisciplinary approach in the teaching of Mathematics. The experience demonstrated that, by integrating Mathematics Education with topics such as sustainability, it is possible to engage students in global issues, encouraging critical reflection and the adoption of more conscious and responsible practices.

With this activity, the undergraduate student reinforced her pedagogical training and highlighted the potential of Mathematics as a tool for social and environmental transformation, demonstrating how educators can contribute to the construction of a more sustainable future.

FOOD PRODUCTION WITH THE USE OF LEACHATE: INTEGRATION OF SUSTAINABLE PRACTICES AND MATHEMATICS EDUCATION

After the success in the production of leachate, the licentiate student was challenged to continue the project by growing food using the liquid fertilizer produced in the composter. This stage sought to further connect the concepts of sustainability and Mathematics, highlighting the complete cycle of reuse of organic waste: waste generation, leachate production and use of fertilizer to stimulate the cultivation of new foods. This activity was designed to integrate sustainable practices into the daily life of the licentiate student and explore its pedagogical potential, promoting an interdisciplinary and contextualized education.

Task description and crop preparation

To carry out the activity, the licentiate student followed the instructions described in Task 5. The proposal involved planting food in recycled containers, such as PET bottles or ice cream jars, filled with black earth or fertilized soil. The food chosen by the licentiate student was coriander, an aromatic herb widely used in Brazilian cuisine. The choice of

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cilantro was strategic, considering its relatively short growth cycle, which would allow us to observe the results of the leachate application in a reduced period of time.

Stages Completed:

1. Container Preparation:
   - The licentiate used a recycled vase filled with black earth. This material was chosen for its richness in essential nutrients for the healthy growth of plants.
2. Planting the Seeds:
   - The coriander seeds were evenly distributed on the surface of the earth and lightly covered with a thin layer of soil. This method was based on the guidance provided by the guides recommended in the task.
3. Dilution and Application of Slurry:
   - The leachate produced in the composter was diluted in the proportion of 1 tablespoon for each liter of water, according to the guidelines of the activity. This dilution was crucial to avoid excess nutrients, which could harm plant development.
   - The first application of the diluted slurry occurred on the 22nd day, when the seeds began to germinate, marking the beginning of seedling growth.

Growth observation and monitoring

The growth process was documented by the licentiate with photos taken on the 22nd, 40th, 49th and 60th days after planting. This visual record allowed us to follow in detail the changes in plant development over time.

- Day 22 (Germination): Small shoots began to appear on the soil surface, indicating that the germination process had been successful. The application of diluted leachate was carried out at this early stage to stimulate the growth of the seedlings.
- 40th day: The seedlings showed significant growth, with more defined leaves and a more robust structure. The licentiate student observed that the regular use of diluted leachate contributed to a uniform and healthy development of the plants.
- 49th and 60th days: On the 49th day, the plants were already in full growth, with a higher density of leaves and intense green color. On the 60th day, the cilantro reached its maturity, being ready for harvest. This milestone completed the cycle

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started with the production of organic waste, demonstrating the feasibility of sustainable reuse.

Table 5: Vegetable Production.

Task 5: Finally, fill a PET bottle or a tub of ice cream, among others, with black earth or fertilized soil and plant one of the following foods: carrots, parsley, rosemary, coriander or chives. During this process, use the slurry produced in the previous Task.
https://www.mds.gov.br/webarquivos/arquivo/seguranca_alimentar/hortas_pedagogicas/Arquivos%20finais%20PHP/manual-pratico-instalacao.pdf
https://jardim.biz/como-plantar-cenoura/
https://www.youtube.com/watch?v=P8JzvIfDF2M
https://www.youtube.com/watch?v=hdxUBRmiJr4
https://www.youtube.com/watch?v=1Of5UFw9BUY

The food I decided to plant was cilantro. The photos below demonstrate the development of the plant. The leachate produced by the composter was diluted in the proportion of 1 tablespoon of leachate to 1 liter of water. The diluted leachate was applied to the plant on the 22nd day, when it was possible to observe the germination of coriander seeds. The photos below correspond to the day of planting (1st photo), 22nd day (date on which germination and application of the diluted leachate occurred) and 28th day.

The photos below correspond to the 40th day, 49th day and 60th day, respectively.

Source: Prepared by the author (2023)

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Mathematical analysis and pedagogical reflections

In addition to documenting the growth of the plants, the licentiate student performed mathematical calculations to analyze the results obtained and project possible future applications.

Calculations made:

1. Growth Time Estimate:
   - If the average time for cilantro to reach maturity was 60 days, what would be the time needed to grow three consecutive cycles, considering that each cycle uses the slurry generated previously?

$$60 \text{ dias X } 3 = 180 \text{ dias}$$

2. Projection of Required Slurry Production:
   - If each application of diluted slurry requires 1 liter of solution (1 tablespoon of slurry for 1 liter of water), and the application occurs weekly, how many liters of solution would be needed for 60 days?

$$\text{Número de Semanas} = \frac{60}{7} \cong 8{,}57 \text{ semanas}$$

Thus, approximately 9 applications would be needed, resulting in 9 liters of diluted solution.

Pedagogical impacts

These calculations not only reinforce mathematical concepts such as proportionality, projection, and estimates, but also connect mathematics to sustainable and everyday practices. According to Skovsmose (2001), contextualized activities such as this make learning more meaningful and relevant for students, while promoting critical reflection on environmental problems.

Benefits and connection to sustainable education

The cultivation activity with the use of leachate highlighted the importance of sustainable practices that promote the reuse of resources and the reduction of waste. By

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using organic waste to produce fertilizer and, later, grow food, the licentiate student closed an ecological cycle that can be replicated in various contexts.

In addition, the assignment illustrated how Mathematics can be integrated with Environmental Education to address global issues such as food security, waste reduction, and sustainable agricultural practices. The cultivation of coriander served as a practical example of how educators can combine mathematical concepts with sustainable practices in basic education, encouraging students to become active agents in building a more balanced and conscious future.

The production of food using leachate highlighted the importance of interdisciplinarity in teaching, connecting Mathematics, Science and Environmental Education in a practical and meaningful way. Experience has shown that Mathematics, when contextualized in real issues, can transform learning into a tool for awareness and sustainable action. The undergraduate student concluded that this pedagogical approach is essential to form critical, responsible citizens committed to sustainability.

ANALYSIS: INTEGRATION BETWEEN MATHEMATICS, SUSTAINABILITY AND PRACTICAL EDUCATION

The project described in this report represents a significant example of how the integration between Mathematics, sustainability and pedagogical practices can transform teaching into a contextualized and interdisciplinary experience. The activities developed demonstrate that Mathematics, when connected to real problems, transcends its abstract character, assuming a relevant role in the formation of critical and conscious citizens. Next, the main virtues and limitations of the study are discussed, highlighting the articulation between theory and practice and the pedagogical implications of this approach.

One of the main virtues of the project is its ability to contextualize Mathematics through real problems. Activities such as solid waste analysis, mathematical problem formulation, and the use of slurry in food cultivation illustrate how concepts such as proportionality, percentage, statistics, and the rule of three can be applied in a practical and meaningful way. As defended by Skovsmose (2001), mathematical learning must be contextualized in everyday situations so that students understand its relevance. This study exemplifies this perspective by enabling participants to not only master the calculations, but also to critically reflect on contemporary environmental issues such as solid waste management.

Another strength of the project is the development of interdisciplinary skills. By integrating Mathematics with Biology, Environmental Education and sustainable practices, the activities met the guidelines of the National Common Curriculum Base (BNCC), which advocates a transversal approach in teaching. The collection and categorization of waste, the production of leachate and the cultivation of food show that interdisciplinarity not only enriches learning, but also prepares students to deal with complex problems, such as sustainability, in an integrated and critical way.

In addition, the project has a high potential for replicability. The proposed activities use accessible materials, such as PET bottles and organic waste, making them feasible in school contexts with limited resources. This simplicity favors implementation in public schools and educational institutions, expanding the social impact and allowing students from different realities to participate in pedagogical practices aimed at sustainability.

Another merit is in the critical training of teachers. The realization of the activities at home by the licentiate promoted a direct involvement with the themes, highlighting the importance of connecting theoretical learning to daily practice. This approach is aligned with D'Ambrosio's (2002) Ethnomathematics, which values local knowledge and lived experiences, demonstrating that the teaching of Mathematics can benefit from integration with everyday cultural and environmental practices.

Despite the virtues presented, the study has limitations that need to be considered. One of them is the lack of diversification of statistical data. While the project explored calculations such as mean, median, standard deviation, and proportion, the analysis could be expanded by introducing more variables or comparing it to regional and global waste generation patterns. This expansion would allow for a more robust discussion on environmental impacts in different contexts and would enrich the results.

Another limitation is the restricted sample scale. The data were collected in only one household, which makes it difficult to generalize the results and identify broader patterns of waste production and disposal. To make the study more representative, it would be interesting to expand data collection to multiple households or schools, allowing for a more comprehensive and comparative analysis.

In addition, the complexity of some statistical analyses can be challenging for elementary school students. While standard deviation calculations and other advanced concepts are relevant, the inclusion of visual representations such as graphs and diagrams

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could make it easier to interpret the results and make learning more accessible for different age groups.

Another point to be improved is long-term monitoring. Although the production of slurry and the cultivation of coriander showed promising results, the monitoring was limited to a single cycle. Observing additional cycles, including the reuse of slurry in new crops, could provide more complete data on the efficiency of natural fertilizer and the cumulative impacts on soil and plants.

In summary, the project demonstrated the potential of integrating Mathematics and sustainability to engage students and teachers in relevant and contemporary issues. The articulation between theory and practice, based on the perspectives of Skovsmose and D'Ambrosio, gave the study a critical and innovative character. However, it is recommended to expand the scale and duration of activities, diversify the data analyzed, and use visual representations to make learning more accessible and comprehensive. By overcoming these limitations, the project will be able to consolidate itself as a reference in pedagogical practices that combine Mathematics Education with the promotion of sustainability and the formation of more aware and engaged citizens.

FINAL CONSIDERATIONS

The analysis of the activities developed throughout this study highlights the vast pedagogical potential of the integration between Mathematics and sustainability in the educational context. The proposal addressed, centered on the collection and analysis of solid waste, leachate production and food cultivation, demonstrated that simple and accessible practices can transform Mathematics into a tool for critical reflection and social action. By connecting mathematical concepts to real environmental problems, the project was able to engage the undergraduate, encouraging her to rethink consumption habits and develop creative solutions to contemporary global challenges, such as inadequate waste management and the need for more sustainable practices.

The articulation with the theories of Skovsmose and D'Ambrosio was one of the main pillars that supported the project. Critical Mathematics Education, proposed by Skovsmose, enabled an approach that goes beyond technical education, stimulating reflection on the social and environmental impacts of human practices. On the other hand, D'Ambrosio's Ethnomathematics brought to the center of the discussion the valorization of local knowledge and daily practices, such as the reuse of waste and composting,

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connecting academic learning to the concrete experiences of the licentiate. This theoretical fusion gave the activity a robustness that transcends the simple application of calculations, inserting Mathematics in a context of social transformation.

Among the most significant results, the potential of Mathematics as a mediator of changes in mentality stands out. The analysis of data on solid waste, the calculation of proportions and percentages, as well as the use of statistical concepts, allowed the undergraduate student to quantitatively understand the impact of daily actions on the environment. This understanding, combined with the practice of composting and growing food, reinforced the idea that sustainable practices can be implemented with limited resources and adapted to different realities, including in low-infrastructure school contexts.

Despite the advances, the project presented limitations that deserve attention in future developments. The representativeness of the data, for example, was restricted to a single household, which made it impossible to carry out a broader analysis of waste generation patterns in diversified contexts. In addition, the monitoring of the composting and cultivation cycle was limited to a single cycle, which prevented the observation of the cumulative impacts of the continuous use of leachate as fertilizer. These gaps suggest that, in future investigations, expanding the scale and duration of activities can offer more comprehensive results that are applicable to different contexts.

Additionally, the use of digital technologies for data collection and analysis could further enrich the project. Tools such as statistical software, modeling applications, and interactive platforms could make it easier to record and interpret data, as well as allow for more detailed comparisons between different contexts. The insertion of these technologies would not only modernize the pedagogical approach, but also prepare students for a world that is increasingly driven by data and critical analysis.

Another relevant aspect is the replicability of the project in school contexts. The simplicity of the materials used, such as PET bottles and household waste, and the possibility of contextualizing the activities according to the local reality make the proposal highly viable in public and private schools. However, teacher training emerges as a crucial point for the success of implementation. Teachers trained to integrate sustainability and Mathematics in an interdisciplinary approach are key to ensuring that the project's objectives are fully achieved. Thus, investments in continuing education programs that emphasize interdisciplinary practices and the use of educational technologies are recommended.

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Finally, the impact of the project goes beyond the academic environment, promoting education for citizenship and sustainability. By associating mathematical concepts with issues such as recycling, waste reduction and food security, the activity encourages students to act as agents of transformation in their communities. This approach is in line with the Sustainable Development Goals (SDGs), which emphasize the need for quality education that prepares citizens who are aware of and engaged with global challenges.

In summary, the study demonstrates that Mathematics, when contextualized and integrated with social and environmental issues, can play a central role in the formation of critical and responsible citizens. Despite some limitations, the project achieved significant results, showing that simple activities, based on real problems, have the power to transform the perception of Mathematics and expand its relevance in building a more sustainable future. It is recommended that future studies deepen the scale and duration of activities, expand the use of technologies and encourage teacher training, so that the practices presented can be implemented effectively and inspiringly in different educational contexts.

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