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From Educational Action to the Development of a School Curriculum: A Strategy for Household Solid Waste Management in the Lukunga Health District

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Abstract

Household solid waste management is a significant challenge in the Lukunga health zone of Kinshasa. This issue is exacerbated by rapid urban growth and population increase. A quasi-experimental study was conducted with 250 students and 12 teachers, divided into experimental (informed) and control (uninformed) groups. The educational intervention increased knowledge about waste types (with an increase from 40% to 60% for household waste). It also promoted sustainable actions such as sorting and composting, with 60% of non-recycled waste being reused or treated after the intervention, compared to 15% in the uninformed group. Statistical analyses confirmed the effectiveness of this approach. These results highlight the importance of integrating waste management education into school curricula to raise youth awareness of environmental issues. The study proposes a structured curriculum tailored to each educational level, including practical activities such as composting and community projects. This method encourages participation to ensure effective implementation by involving both teachers and students. In conclusion, environmental education appears to be essential for promoting sustainable waste management and fostering a generation that is aware of and concerned about environmental protection.

Keywords

Educational Action, School Curriculum, Management, Household Solid Waste

1. Introduction

Each year, more than two billion tons of solid waste are produced globally, with at least a significant portion not receiving adequate treatment [1]. Kinshasa, the capital of the Democratic Republic of the Congo, is no exception. In the Lukunga health district, population growth and urban expansion have intensified waste management problems, with waste accumulating due to insufficient collection resources and non-compliance with disposal regulations [2]. Consequently, the environment and public health suffer, with unauthorized dumpsites proliferating, increased filth, and growing health risks [3].

A significant proportion of the population continues to dispose of waste in unauthorized areas such as streets, vacant lots, or waterways [2]. This behavior often results from limited access to appropriate collection infrastructure and insufficient awareness of the environmental and health impacts of such practices [4]. There is also a widespread perception that waste management is solely the responsibility of public authorities, reinforcing individual disengagement.

While some individuals adopt environmentally responsible behaviors such as composting or reusing waste for urban agriculture or crafts, these initiatives remain marginal. Informal waste pickers, despite their role in waste reduction, lack structure and official recognition, limiting their effectiveness [5].

Source separation is almost nonexistent in households, where waste is typically mixed, complicating treatment and reducing recycling opportunities. Although some residents recognize waste as a threat to the environment and public health, this awareness is insufficient given the scale of the problem.

Community initiatives for waste management are rare and struggle to develop due to a lack of collective awareness and insufficient coordination between residents and local authorities (A more integrated approach—combining environmental education, infrastructure improvement, and recognition of informal actors—could help reverse this trend [6]).

Faced with these challenges, waste management education offers hope for informing residents and encouraging appropriate behaviors [7]. Various actions have shown that educational interventions can play a central role in changing both individual and collective behaviors by increasing awareness of the environmental and health consequences of waste.

Willy Bakonga, who was serving as Minister of Primary Education at the time, underscored the significance of this initiative, stating: "It is crucial that children develop a culture of environmental protection, encompassing soil, water, air, forest, etc." [8].

Despite these advances, effective responses to sanitation and environmental challenges require a curriculum specifically dedicated to waste management, building on UNESCO's recommendations for practical, action-oriented learning [9]. This study aims to analyze the impact of educational actions on waste management in Lukunga and propose an adapted school curriculum.

2. Materials and Methods

2.1. Study Design

A quasi-experimental study was conducted in the Lukunga health district, targeting students and teachers from two schools.

2.2. Sampling

Schools in the district were selected based on three main criteria: geographical proximity (schools located at a reasonable distance from each other to prevent cross-group contamination or influence), the socioeconomic diversity of the neighborhoods they represent (based on income level and access to waste management infrastructure), and the size of the student body.

The inclusion and exclusion criteria for students were as follows:

- Enrollment in the 5th or 6th year of secondary school within the Lukunga district;
- Age between 15 and 18 years;
- Availability on the day of the survey.

Students who had already received training in waste management were excluded to avoid bias related to pre-existing knowledge.

The sample size was determined using Yamane's formula [10], a statistical method commonly employed for estimating sample sizes in finite and relatively homogeneous populations. This approach is particularly appropriate for research in the social sciences, where it is essential to control the margin of error and the confidence level.

The formula used is expressed as follows:

$$n = \frac{N}{1 + N \cdot e^2}$$

where:

n = desired sample size

N = total population size

e = margin of error (level of precision)

In this study, the sample size was calculated as follows:

$$n = \frac{N}{1 + N \cdot e^2} = \frac{250}{1 + 250(0.05)^2} = \frac{250}{1 + 250 \cdot 0.0025} = \frac{250}{1.625} = 154 \text{ students}$$

Or:

$e^2 = 0.05^2 = 0.0025$

$N \cdot e^2 = 250 \cdot 0.0025 = 0.625$

$1 + 0.625 = 1.625$

$n = \frac{250}{1.625} \approx 154$ students

Thus, the theoretical sample is 154 students (77 per group).

2.2.1. Adjustment for Attrition and Operational Constraints

To ensure the validity of the results despite field challenges—such as absenteeism

(students sick or absent on the survey day), exclusions (incomplete questionnaires or failure to meet inclusion criteria), and attrition (dropouts due to relocation or refusal to participate)—a 30% safety margin was applied, following WHO recommendations for surveys in dense urban areas [11].

The selection of the sample of 100 students per group was carried out using a probabilistic sampling method, specifically simple random sampling (SRS). This method ensures the representativeness and impartiality of the results by giving each student in the total population (i.e., 250 students) an equal chance of being selected. After adjustment, the sample size is approximately 200 students, corresponding to 100 per group (adjusted $n = 154 \times 1.3 \approx 200$ students, or 100 per group). The distribution of participants is summarized in **Table 1**.

Table 1. Summary of sample sizes.

Group	Theoretical Size	Adjustment (+30%)	Final Size
Intervention	77	23	100
Control	77	23	100
Total	154	46	200

To achieve this, a complete list of students meeting the inclusion criteria was first established, and each student was assigned a unique identifier, numbered 1 to 250. The selection of 100 students per group was then carried out by random draw using Microsoft Excel's = RANDBETWEEN() function to generate random values associated with each identifier, followed by sorting based on these values. The first 100 identifiers in each group were selected as the final sample.

2.2.2. Verification

After this step, it was essential to verify that the selected students strictly met the inclusion criteria, particularly their grade level and availability. In cases of unavailability or exclusion (e.g., absence on the survey day or non-compliance with criteria), an additional draw was conducted to complete the sample while preserving the random nature of the selection process.

As part of the development of a new school curriculum on waste management education, an exploratory study was conducted to gather teachers' perspectives on content, pedagogical approaches, and training needs.

2.2.3. Teacher Inclusion Criteria

- Teachers of the final years (5th and 6th years);
- At least 3 years of teaching experience;
- Currently employed in one of the selected schools;
- Provided informed consent to participate in the study;
- Available on the scheduled dates for interviews or focus groups.

2.2.4. Selection Procedure

A nominal list of all teachers employed in the two selected schools was obtained from school management. From this list, only teachers meeting the inclusion criteria were retained. Of the 18 teachers identified, 12 met the criteria. As only 3 teachers per school were needed, a simple random draw was conducted among eligible teachers using the = RANDBETWEEN() function in Microsoft Excel to ensure neutrality. Selected teachers were informed of their inclusion and provided with a consent form. In cases of refusal or unavailability, a replacement was selected from a reserve list generated during the initial draw.

Regarding qualitative data, selected teachers were invited to share their pedagogical preferences, learning objectives, and the challenges they face. These discussions were conducted in focus groups, conducive to creativity and the generation of innovative ideas.

2.3. Data Collection

Three phases: pre-intervention questionnaire, educational intervention, and post-intervention questionnaire. The questionnaire assessed knowledge and behaviors related to waste management.

Data analysis was conducted in two steps:

1) ***Univariate Analysis***: Frequency and percentage tables were generated for each question, before and after the intervention, as well as for the control group, to isolate the effect of the intervention.

2) ***Bivariate Analysis***: Cross-tabulations were created between the dependent variable (prior information) and independent variables. P-values, chi-square (χ^2), and degrees of freedom were calculated for each table. The results were compared to the critical value of χ^2. A pre/post intervention comparison was performed by evaluating the χ^2 values obtained for each question.

3. Results

The data presented in Table 2 illustrate the impact of the intervention on students' understanding of waste categories, as follows:

- *Experimental group*: The intervention led to a significant increase in the proportion of students identifying household waste (60%) and economic activity waste (50%). There was also a rise in the recognition of hazardous and "other" waste, reflecting a more comprehensive understanding overall.
- *Control group*: Changes were less pronounced, with moderate increases in the identification of household waste (45%) and economic activity waste (35%).
- *Intergroup comparison*: The informed group exhibited higher proportions in all categories, demonstrating the effectiveness of the intervention.

These results demonstrate that the intervention had a positive impact on knowledge of waste categories.

Figure 1 further highlights the influence of the intervention on the distribution of different types of waste.

Table 2. Categories of main types of waste.

Group	Waste Category	Period	Number (n = 100)	%	Number (n = 100)	%
Experimental group	Household waste	Before	40	40	60	60
	Economic activity waste		30	30	50	50
	Hazardous waste		20	20	30	30
	Other		10	10	20	20
Control group	Household waste	Before	35	35	45	45
	Economic activity waste		25	25	35	35
	Hazardous waste		15	15	25	25
	Other		25	25	15	15
Intergroup (After intervention)	Household waste	After	60	60	45	45
	Economic activity waste		50	50	35	35
	Hazardous waste		30	30	25	25
	Other		20	20	15	15

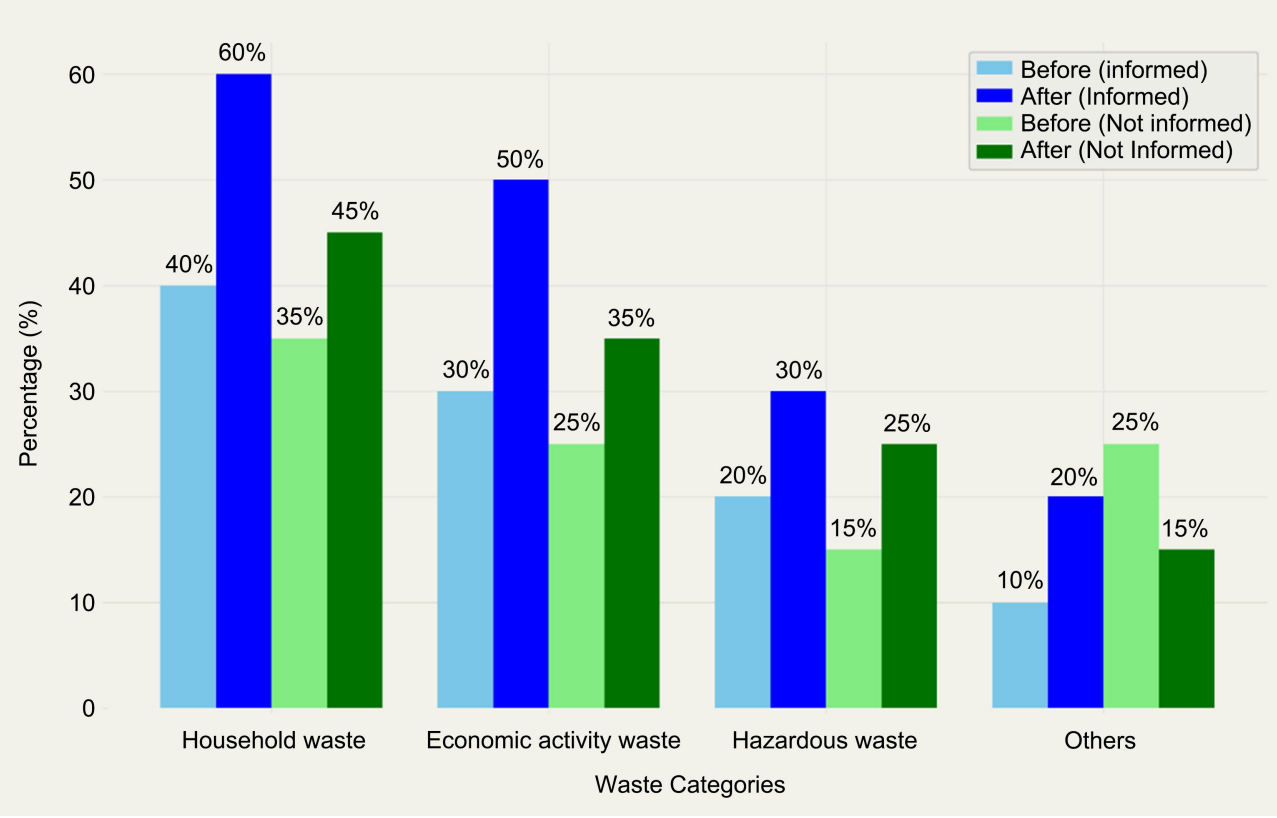

Figure 1. Impact of the intervention on waste categories.

- *Experimental group* (*Informed*): Prior to the intervention, household waste accounted for 40% and economic activity waste for 30%. After the intervention, these proportions increased significantly to 60% and 50%, respectively. There was also a moderate increase in hazardous and "other" waste.
- *Control group* (*Uninformed*): Changes were less marked. Household waste increased from 35% to 45%, and economic activity waste from 25% to 35%, while the other categories showed minor variations.
- *Intergroup comparison after intervention*: The informed group displayed substantially higher proportions in all categories compared to the uninformed group, confirming the effectiveness of the interventionfn1.

This figure clearly demonstrates the positive impact of the information provided on waste management, particularly within the informed experimental group.

The data of Table 3 statistically reveal the relationship between the main waste categories and having received information on waste management:

- *Experimental group* (*Informed*): The chi-square value is 25.1234 with a p-value < 0.001, indicating a notable or highly significant difference.
- *Control group* (*Uninformed*): The chi-square value is 10.5678, with a p-value of 0.0345, indicating a moderate but significant difference.
- *Intergroup comparison after intervention*: The chi-square value is 8.2345, with a p-value of 0.0456, demonstrating a statistically significant difference between the two groups.

Table 3. Relationship between main waste categories and having received information on waste management.

Group	Period	Household waste	Economic activity waste	Hazardous waste	Other	Total	χ^2	df	p
Experimental	Before	40	30	20	10	100	-	-	-
Experimental	After	60	50	30	20	100	25.1234	3	<0.001
Control	Before	35	25	15	25	100	-	-	-
Control	After	45	35	25	15	100	10.5678	3	0.0345
Intergroup (After)		60	50	30	20	100	-	-	-
Intergroup (After)		45	35	25	15	100	8.2345	3	0.0456

These results indicate that the intervention had a significant impact on the perception of waste categories in the experimental group, with a marked improvement in the informed group, particularly for household and economic activity waste.

Table 4, for its part, reveals that the intervention on the importance of sorting waste had the following effects:

- *Experimental Group* (*Informed*): Before the intervention, participants attributed moderate importance to all variables, with a slight preference for reducing pol-

lution (30%) and protecting health (25%). After the intervention, there was a significant increase in the importance given to reducing pollution (50%) and conserving resources (35%), while the importance given to facilitating recycling and protecting health decreased.

- *Control Group* (*Uninformed*): Before the intervention, participants attributed slightly more importance to conserving resources (30%) and reducing pollution (25%). After the intervention, there was an increase in the importance given to reducing pollution (40%) and stability for conserving resources (30%).
- *Comparison Between Groups*: The informed group gave more importance to reducing pollution (50%) and conserving resources (35%) than the uninformed group.

Table 4. Importance of sorting waste.

Group	Benefits of pollution reduction	Period			
		Before		After	
		Number n = 100	%	Number n = 100	%
Experimental group	Reduce pollution	30	30	50	50
	Conserve resources	25	25	35	35
	Facilitate recycling	20	20	10	10
	Protect health	25	25	5	5
Control group	Reduce pollution	25	25	40	40
	Conserve resources	30	30	30	30
	Facilitate recycling	25	25	20	20
	Protect health	20	20	10	10
Intergroup comparison (after intervention)	Benefits of pollution reduction	After intervention			
		Informed group	%	Uninformed group	%
	Reduce pollution	50	50	40	40
	Conserve resources	35	35	30	30
	Facilitate recycling	10	10	20	20
	Protect health	5	5	10	10
		100	100	100	100

For these data, the intervention changed the order of expected benefits regarding pollution reduction. Greater interest was given to pollution reduction and resource conservation. This approach reduced a more comprehensive perspective

that also included health and recycling.

The data in Table 5 on the relationship between knowledge of the benefits of waste reduction and having been informed about waste management statistically explain the following:

- *Experimental Group* (*Informed*): The cross-analysis between "benefits of waste reduction and having been informed about waste management before this intervention" shows a chi-square of 23.3333, with a p-value less than 0.001. This indicates a statistically significant association between these two variables.
- *Control Group* (*Uninformed*): The analysis reveals a chi-square of 7.35 with a p-value of 0.0615. This result indicates a trend toward a significant difference, although it does not reach the conventional threshold for statistical significance.
- *Intergroup Comparison After the Intervention*: The chi-square is 6.4957, with a p-value of 0.0898, showing no statistically significant difference between the groups.

Table 5. Relationship between benefits of waste reduction and having been informed about waste management.

Group	Period	reduce pollution	Conserve resources	Facilitate recycling	Protect health	Total	χ^2	df	p
Experimental	Before	30	25	20	25	100			
	After	50	35	10	5	100	23.3333	3	<0.001
Control	Before	25	30	25	20	100			
	After	40	30	20	10	100	7.3504	3	0.0615
Intergroup	After	50	35	10	5	100			
	After	40	30	20	10	100	6.4957	3	0.0898

These results demonstrate that the intervention had a significant effect on the perception of the benefits of waste reduction within the experimental group, with a clear increase in the importance given to pollution reduction. This indicates that the intervention was effective in changing participants' views within the experimental group.

For Table 6 on the fate of non-recycled waste, the educational intervention shows the following:

- *Experimental Group*: Before the intervention, the majority of non-recycled waste was "landfilled" (40%) or "incinerated" (30%), with only 10% reused or treated. After the intervention, there was a sharp reduction in "landfilled" waste (−20 points) and "incinerated" waste (−15 points) in favor of "reused or treated" waste (+50 points).
- *Control Group*: The changes are less marked: "landfilled" waste decreases slightly (45% to 40%) and "reused or treated" increases modestly (10% to 15%).

- *Intergroup Comparison* (*After Intervention*): The informed group showed a much higher proportion of "reused or treated" waste (60% vs. 15%) and much less "landfilled" waste (20% vs. 40%) compared to the uninformed group.

Table 6. Fate of non-recycled waste.

Group	Fate of non-recycled waste	Period			
		Before		After	
		Number n = 100	%	Number n = 100	%
Experimental group	Landfilled	40	40	20	20
	Incinerated	30	30	15	15
	Dumped in nature	20	20	5	5
	Reused or treated	10	10	60	60
Control group	Landfilled	45	45	40	40
	Incinerated	25	25	30	30
	Dumped in nature	20	20	15	15
	Reused or treated	10	10	15	15
Intergroup comparison (after intervention)	Fate of non-recycled waste	After intervention			
		Informed group	%	Uninformed group	%
	Landfilled	20	20	40	40
	Incinerated	15	15	30	30
	Dumped in nature	5	5	15	15
	Reused or treated	60	60	15	15
		100	100	100	100

The data reveal that information on waste management has a significant impact, with a marked shift toward more sustainable practices in the experimental group.

The results of Table 7 demonstrate the relationship between the fate of non-recycled waste and having been informed about waste management as follows:

- *Experimental Group* (*Informed*): The chi-square is 35.6789, with a p-value < 0.001, indicating a highly significant difference.
- *Control Group* (*Uninformed*): The chi-square is 8.2345, with a p-value of 0.0412, indicating a moderate but significant difference.
- *Intergroup Comparison After Intervention*: The chi-square is 18.4567, with a p-value < 0.001, indicating a statistically significant difference between the two groups.

Table 7. Relationship between fate of non-recycled waste and having been informed about waste management.

Group	Period	Landfilled	Incinerated	Dumped in nature	Reused or treated	Total	χ^2	df	p
Experimental	Before	40	30	20	10	100			
	After	20	15	5	60	100	35.6789	3	<0.001
Control	Before	45	25	20	10	100			
	After	40	30	15	15	100	8.2345	3	0.0412
Intergroup	After	20	15	5	60	100			
	After	40	30	15	15	100	18.4567	3	<0.001

These results clearly indicate that information on waste management has a significant impact on the fate of non-recycled waste, with a marked shift toward more sustainable practices in the informed experimental group.

Table 8 shows the impact of the intervention on students' knowledge of the consequences of non-recycled waste as follows:

- *Experimental Group* (*Informed*): Before the intervention, subjects mainly identified the accumulation of garbage (30%) and the increase in greenhouse gases (25%) as consequences of lack of waste recycling. After the intervention, there was a significant increase in the perception of garbage accumulation (55%) and a decrease in the perception of sea contamination (5%).
- *Control Group* (*Uninformed*): Before the intervention, subjects mainly identified the increase in greenhouse gases (30%) and sea contamination (25%). After the intervention, there was an increase in the perception of garbage accumulation (40%) and a decrease in sea contamination (20%).
- *Comparison Between Groups After the Intervention*: The informed group gave more importance to landfill congestion (55%) and less to ocean pollution (5%) than the uninformed group.

These results show that the intervention had a significant effect on the perception of the consequences of non-recycled waste in the experimental group. A strong increase in the perception of waste accumulation was observed. This suggests that the intervention was effective in changing the participants' views within the experimental group.

The results of Table 9 highlight the statistical relationship between the consequences of non-recycled waste and having been informed about waste management as follows:

- *Experimental Group* (*Informed*): The chi-square is 34.4444, with a p-value of 0.001, marking a statistically significant difference.
- *Control Group* (*Uninformed*): The chi-square is 7.3504, with a p-value of 0.0615; this suggests a trend toward a significant difference without reaching the required level for statistical significance.
- *Comparison Between Groups*: The chi-square is 9.4957, with a p-value of 0.0235, highlighting a statistically significant difference between the groups.

Table 8. Consequences of non-recycled waste.

Group	Consequence of non-recycled waste	Period			
		Before		After	
		Number n = 100	%	Number n = 100	%
Experimental group	Landfill congestion	30	30	55	55
	Increase in greenhouse gases	25	25	35	35
	Ocean pollution	20	20	5	5
	Health risks	25	25	5	5
Control group	Landfill congestion	25	25	40	40
	Increase in greenhouse gases	30	30	30	30
	Ocean pollution	25	25	15	15
	Health risks	20	20	15	15
Intergroup Comparison (After Intervention)	Consequence of non-recycled waste	After intervention			
		Informed group	%	Uninformed group	%
	Landfill congestion	20	20	40	40
	Increase in greenhouse gases	15	15	30	30
	Ocean pollution	5	5	20	20
	Health risks	60	60	10	10
		100	100	100	100

Table 9. Relationship between consequences of non-recycling and having been informed about waste management.

Group	Period	Landfill congestion	Increase in greenhouse gases	Ocean pollution	Health risks	Total	χ^2	df	p
Experimental	Before	30	25	20	25	100			
	After	55	35	5	5	100	34.4444	3	<0.001
Control	Before	25	30	25	20	100			
	After	40	30	20	10	100	7.3504	3	0.0615
Intergroup	After	55	35	5	5	100			
	After	40	30	20	10	100	9.4957	3	0.0235

These results show that the intervention had a significant effect on the perception of the consequences of non-recycled waste in the experimental group. A strong increase in the perception of waste accumulation was observed. This suggests that the intervention was effective in changing the participants' views within the experimental group.

Table 10 indicates that half of the participants (45%) already had some knowledge about waste management before the intervention, while the other half (55%) had not received any information. The fact that more than half of the participants had not been informed suggests that there is a significant need for education and awareness on waste management in this population. However, the intervention could have a significant impact on participants who had not been informed previously, by increasing their level of knowledge and potentially changing their behaviors.

Table 10. Having already been informed about waste management before this intervention.

Response	Frequency	Percentage (%)
Yes	45	45.0
No	55	55.0

Given the observed effectiveness of this educational intervention, we now propose a structured school curriculum to promote sustainable management of household solid waste in the Lukunga health district, Kinshasa.

4. Proposal for a School Curriculum

To develop this curriculum effectively, we adopted a participatory approach [12], actively involving teachers through various consultation methods. This process aimed to design a program tailored to the actual needs of the educational system, while ensuring the commitment of key stakeholders engaged in waste management practices.

Step 1: Consultation with Teachers in Pilot Schools

We began by selecting five pilot schools and requested permission to meet with a carefully chosen sample of teachers. These teachers were invited to share their pedagogical preferences, learning objectives, and the challenges they face. These discussions took place in the form of focus groups, conducive to creativity and the generation of innovative ideas.

Step 2: Collaboration with Education Researchers

Education researchers were informally integrated into the design process, focusing on the development of tools for rigorous evaluation of the program's effectiveness. Their expertise was invaluable in ensuring the pedagogical relevance and coherence of the content developed.

Step 3: Creation of a Collaborative Environment

To foster an atmosphere of collaboration and engagement, we ensured to:

1) Clearly communicate our objectives: From the outset, we presented the framework of our approach and the expectations regarding participants' contributions.

2) Include all voices: Particular attention was paid to considering the opinions of traditionally underrepresented groups, thereby ensuring an inclusive approach.

3) Organize iterative meetings: Each teacher participated in at least two sessions, allowing for deeper exchanges and refinement of proposals.

4) This proactive collaboration laid the foundation for an innovative and adapted program, supported by strong buy-in from teachers and other stakeholders.

4.1. Curriculum Design

Definition of Educational Objectives

We established key competencies to be acquired in waste management and aligned the objectives with national educational standards [13] [14].

Content Development

Modules adapted to different school levels were developed, as well as practical and interactive activities. Essential knowledge and skills to be imparted to students were identified:

- *Practical skills*:
  - Learning proper waste sorting
  - Implementing and using selective collection systems (sorting bins, composting, etc.)
  - Reducing daily waste production
- *Analytical skills*:
  - Identifying different types of waste and their impacts
  - Analyzing the life cycle of products and materials
  - Assessing the effectiveness of implemented actions
- *Social and civic skills*:
  - Engaging in collective projects
  - Raising awareness and mobilizing one's surroundings (family, community)
  - Developing a sense of responsibility toward the environment
- *Creative skills*:
  - Imagining innovative solutions to reduce and valorize waste
  - Designing communication and awareness-raising tools
- *Reflective skills*:
  - Developing critical thinking about consumption patterns
  - Understanding the environmental, social, and economic issues related to waste
- *Transversal skills*:
  - Working in teams and collaborating
  - Planning and organizing concrete actions
  - Communicating effectively about issues and solutions

These competencies are part of an education for sustainable development ap-

proach, aiming to train citizens who are aware and committed to environmental preservation. The co-constructed model allows students to actively and participatively acquire these skills by directly involving them in the design and implementation of waste management solutions adapted to their local context. Table 11 shows different educational modules [14].

Table 11. Design of learning modules.

Level	Educational objectives	Activities
Primary (Grades 1 - 6)	• Raise awareness of waste sorting • Understand the environmental impact of waste • Learn basic waste reduction practices	• Waste sorting games using images or objects • Making objects from recycled materials (musical instruments, pencil holders, etc.) • Visit to a sorting center or waste facility • Creation of posters on proper sorting practices for the school
Middle School (Grades 8 - 9)	• Deepen knowledge of the waste life cycle • Understand the issues of recycling and the circular economy • Develop critical thinking about consumer society	• Survey on household/school waste production over a week • Debate on packaging reduction • Composting workshop • Project to create a mini recycling business
High School (Grades 10 - 13)	• Analyze the environmental, social, and economic impacts of waste management • Understand public policies and regulations related to waste • Reflect on technological and social innovations for improved management	• Case study on waste management in different countries • Calculation of the ecological footprint related to waste • Debate on ethical issues in the international waste trade • Community awareness project

For all levels, it is crucial to adopt an active and participatory pedagogy, involving students in concrete projects. The objective is to develop their skills and empower them as agents of change in their environment.

4.1.1. Integration of Practical Approaches

Suggestions for incorporating practical activities and community projects related to waste management into the school curriculum include:

- Creation of a school composting system
- Creative recycling projects
- Community awareness campaigns
- Cleaning of public spaces
- School waste audits
- Partnerships with local businesses
- Inter-class competitions

These practical activities and community projects will help students develop concrete waste management skills, raise awareness of environmental protection, and strengthen civic engagement.

4.1.2. Pilot Implementation

For the implementation of this educational program, five schools—one per health zone (Mongafula I, Makala, Ngaba, Matete, Kalamu I)—were selected as a representative sample of the Lukunga health district. The school administrations are expected to collaborate with us.

- Teacher training**:** Workshops were organized for teachers on our strategy, providing them with educational resources and ongoing support.
- *Program deployment*: Modules will be gradually introduced in pilot classes, promoting practical waste management projects within schools.

4.1.3. Evaluation and Adjustment

- *Data collection*: Classroom observations, surveys with students and teachers, analysis of mobile application data.
- *Analysis of results*: Assessing students' skill acquisition, measuring the impact on attitudes toward waste management.
- *Program adjustments*: Identifying strengths and areas for improvement, modifying content and teaching methods accordingly.

4.1.4. Scaling Up

- Develop an implementation schedule for all schools in Kinshasa
- Allocate necessary resources (materials, training, support)
- Organize large-scale teacher training sessions and establish a continuous training system
- Set up long-term performance indicators and a regular feedback system

4.1.5. Development of Assessment Tools

Multiple methods were considered to assess knowledge acquisition, including:

- Interactive classroom quizzes
- Behavioral observations
- Practical projects
- Peer assessments
- Family involvement
- Quantitative measures
- Long-term evaluations
- Portfolios
- Problem-based situations
- Collective performance indicators

Combining these methods provides a comprehensive and reliable evaluation of both knowledge acquisition and tangible behavioral changes.

4.1.6. Validation and Adjustment

1) Pilot test: Implementation of the program in a selected sample of schools.

2) Evaluation and feedback: Collection and analysis of feedback from teachers, students, and parents.

3) Model optimization: Adjustment of the management model and pedagogical

framework based on pilot test results.

4.2. Long-Term Monitoring to Assess the Sustainability of Intervention Effects

To ensure the durability of the outcomes observed following the educational intervention, it is essential to implement a long-term monitoring system that combines both quantitative and qualitative indicators over several years. This monitoring relies, in particular, on the regular measurement of individual and collective behaviors (such as selective sorting rates, the percentage of waste reused or composted, and initiatives led by students), annual assessments of knowledge and attitudes using standardized questionnaires, as well as the tracking of measurable environmental impacts (including the quantity of waste generated, the reduction rate of waste sent to landfill, and the volume of compost produced).

Complementary tools, such as direct behavioral observations, individual portfolios documenting student actions, and surveys conducted with families, will help to evaluate the persistence of these practices over time, including after students leave the school system. Ideally, monitoring should occur annually over a period of three to five years, with intermediate evaluation points, to facilitate program adjustment and maintain community engagement.

Table 12. Key indicators for monitoring the impact of the education programs.

Indicator	Frequency	Source(s)	Objective
Rate of integration of health education into school curricula	Annual	School reports, inspections	Evaluate the dissemination and sustainability of health-related educational content within curricula.
Percentage of students adopting healthy behaviors (hygiene, nutrition)	Semiannual	Student surveys, direct observation	Assess the impact of educational initiatives on students' lifestyle choices and habits.
Number of environmental health awareness initiatives conducted by the school	Quarterly	Activity reports, documentation	Quantify the school's commitment to promoting environmental health through various initiatives.
Level of student knowledge about the links between environment and health	Annual	Standardized questionnaires	Monitor the progress in students' educational achievements and their understanding of environmental health issues.
Rate of parental and community participation in awareness activities	Semiannual	Attendance records, family questionnaires	Evaluate the program's influence on family engagement and the broader community dynamics.
Percentage reduction in risky behaviors related to health or the environment	Annual	Audits, surveys, observations	Measure the effectiveness of educational programs aimed at disease prevention and promoting sustainability.
Number of intersectoral partnerships (health, education, environment) developed	Annual	Institutional reports, partnership agreements	Showcase the collaboration between sectors to enhance public health initiatives and their impact.

Finally, the attainment of environmental labels and participation in collective certification processes will serve as performance indicators, highlighting the progress made and encouraging the continued adoption of responsible behaviors within the educational community.

Table 12 summarizes the main recommended indicators for monitoring the sustainability of educational changes in waste management, drawing on approaches from international environmental education guidelines [13] [15].

This table facilitates a systematic observation of how educational initiatives and awareness-raising efforts influence health and the environment. It employs measurable indicators alongside a variety of sources and well-defined objectives to support this analysis.

4.3. Potential Implementation Challenges

- Lack of adequate infrastructure (e.g., sorting bins, composters)
- Absence of regular waste collection services
- Financial constraints
- Cultural and social resistance
- Negative perception of the program as extra work
- Lack of technical skills among teachers
- Absence of ongoing training

Possible solutions include seeking funding from international organizations (UNESCO, AFD, private companies), organizing targeted educational campaigns, implementing specialized waste management training programs; etc. [1] [14].

5. Discussion

The results of this study highlight the significant influence of targeted educational action on secondary students' knowledge and behaviors regarding household solid waste management. The observed progress in the test group, such as increased knowledge of household waste sorting (from 40% to 60%) and the adoption of stable actions like sorting and composting, supports the effectiveness of dynamic and adapted education. These findings are consistent with previous research [6] [16], which demonstrated that contextually adapted educational campaigns significantly increase engagement in selective sorting.

This study proposed a structured curriculum integrating waste management at all school levels, in line with UNESCO recommendations for education for sustainable development [13] [14]. The program emphasizes experiential and participatory learning, aligning with international educational standards. However, as highlighted by McCracken and Phillips, systematic integration of waste management education is still hindered by a lack of dedicated time and insufficient teacher training [17]. Immersive initiatives, such as visits to sorting centers or ecoparks, are also essential for linking theory and practice and enhancing understanding of sustainable waste management processes [14].

Ultimately, this study shows that contextualized and participatory environmen-

tal education is a key lever for promoting responsible waste management behaviors. It also underscores the need for an integrated approach combining active pedagogy, community involvement, and appropriate infrastructure to ensure the sustainability of ecological practices among younger generations.

6. Conclusions

This study highlights the central role of environmental education in promoting responsible behaviors in household solid waste management. The results demonstrate that targeted educational interventions, combining theoretical learning and practical activities, can significantly improve knowledge and encourage the adoption of sustainable practices such as selective sorting and composting. The participatory approach involving teachers and students ensures better ownership of environmental issues and fosters local anchoring of proposed solutions.

The proposal of a structured curriculum, adapted to each school level, represents significant progress for the sustainable integration of waste management into educational practices. Enriched by community projects and immersive activities, this program offers a unique opportunity to connect theory and practice while raising awareness among younger generations about environmental challenges.

However, to maximize the impact of these initiatives, it is essential to ensure long-term monitoring, strengthen teacher training, and develop appropriate infrastructure in schools. Ultimately, this study demonstrates that contextualized and participatory environmental education is a powerful lever for building a society that is aware of ecological issues and capable of adopting sustainable solutions to global environmental challenges.

7. Recommendations

1) Institutionalization: Officially integrate the proposed curriculum into school programs; systematically include waste management topics in curricula in a transversal and interdisciplinary manner from primary school onward.

2) Continuing education: Strengthen teachers' capacities to ensure effective program implementation.

3) Monitoring and evaluation: Establish a regular evaluation system to measure the program's impact on students' knowledge and behaviors.

4) Extension: Gradually extend the program to other schools to amplify its impact.

5) Local partnerships: Involve local authorities, NGOs, and recycling sector companies to create synergies and strengthen the impact of school initiatives in the territory.

8. Research Perspectives

This study opens several avenues for research. It would be relevant to evaluate the long-term effects of this type of educational intervention on students' environ-

mental behaviors, particularly after they leave the school system. A longitudinal analysis would determine whether the knowledge and practices acquired persist over time and influence adult life. Comparative studies between different regions or countries would help identify contextual factors affecting the effectiveness of environmental education programs. Finally, analyzing the socio-economic impacts of quality environmental education on local communities would be a promising research field, in line with sustainable development goals.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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