

# Pedagogical program based on the 3Rs to improve solid waste management in students of an educational institution in the city of Huancayo

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**Abstract.** The purpose was to evaluate the effectiveness of the pedagogical program "School Ecoaction 3R", based on the 3Rs to improve the process followed by the solid waste of the students of the educational institution "Ramiro Villaverde Lazo" in the city of Huancayo. The population was 299 students. The sample was made up of 169 randomly selected students from 3rd, 4th and 5th grade. The pedagogical program was applied to this group. The methodology was applied, explanatory level and pre-experimental design with pre- and post-test. A checklist was used to measure the management of solid waste and its dimensions prevention or minimization, valuation or recovery and final disposal. It was found that there are differences between the results before and after the application of the sessions. 90.5% of the students in the post-test were graded at an adequate level, while in the post-test no student had that grade. On the side of the inferential test, the rank test yielded a p-value of 0.00 indicating that the differences between the pre- and post-test are significant. From this it is concluded that the application of the pedagogical program "School Ecoaction 3R" was effective in improving the solid waste management of students in the school.

## 1. Introduction

Accelerated urban expansion, unregulated population growth and the prevalence of linear consumption schemes have given rise to one of the most relevant environmental crises of recent decades: the excessive production of solid waste. This phenomenon not only compromises ecosystems, but also has a direct impact on public health and quality of life, especially in urban contexts in developing countries. In current times, solid waste generation is projected to increase from 2,300 million tons in 2023 to 3,800 million tons by 2050. Likewise, the annual global cost would double to \$640300 million; This reality represents a global environmental threat, exacerbated by inadequate practices such as clandestine dumping, open burning and the limited institutional capacity for its effective management, [1].

In Latin America, the situation is no less alarming. The "Economic Commission for Latin America and the Caribbean" (ECLAC) estimates that around 541 thousand tons of solid waste are produced daily in the region, of which a considerable part lacks adequate treatment. . In Peru, the Ministry of the Environment reports a daily production of 20,000 tons, of which less than 20% is disposed of in authorized sanitary landfills. This reality is more serious in intermediate cities such as Huancayo, where limitations in infrastructure, environmental education and citizen participation make it difficult to implement sustainable policies, negatively impacting

collective health. Inadequate waste management is directly linked to the increase in infectious diseases, as well as to respiratory and gastrointestinal conditions, as well as to the contamination of basic elements such as soil, water, and air, [2], [3], [4], [5].

Faced with this problem, the implementation of educational programs based on the philosophy of the 3Rs: reduce, reuse and recycle emerges as an effective alternative. These programs allow not only to mitigate the volume of waste generated, but also to promote a critical and active environmental awareness from an early age. Recent studies argue that the incorporation of participatory methodologies in schools increases the effectiveness of waste management programs, by linking theory with everyday practices that reinforce the student's socio-environmental commitment, [6, 7], [8, 9].

In this framework, the purpose of the study was to analyze the effectiveness of a pedagogical program based on the 3Rs strategy, aimed at optimizing solid waste management practices in students of a school in Huancayo. The relevance of this work lies in its potential to propose a replicable strategy that articulates environmental education and citizen participation, aligned with the principles of the circular economy and the SDGs, [8, 10].

In this sense, the research is supported by its social, environmental and educational relevance, both locally and globally, in the face of the progressive increase in solid waste and its negative repercussions on the environment and public health. Specifically, in the city of Huancayo

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there is a marked lack of coordination between the production of waste, its final disposal and the level of citizen awareness, a situation that results in inappropriate practices such as the accumulation of garbage in common areas, the informal burning of waste and the limited involvement of the school community in sustainable management initiatives, [3].

In this framework, the creation and implementation of a pedagogical program based on the 3R strategy constitutes an innovative and formative alternative, aimed not only at optimizing solid waste management in the school environment, but also at promoting environmentally aware citizenship from the early stages of education. This educational proposal is based on participatory and active learning approaches, aligned with the development of citizenship, ecological and social competencies, [4, 7].

At the international level, this initiative is directly linked to the SDGs established in the UN 2030 Agenda. First, the study promotes SDG 4: Quality education, by systematically incorporating environmental education content into school education, strengthening sustainable values, attitudes and practices. In the same way, it contributes to the fulfillment of SDG 11: Sustainable cities and communities, by promoting a cleaner, healthier and more participatory urban environment, through the strengthening of the culture of segregation at the source and the responsible management of waste. In the same way, it contributes to SDG 12: Responsible production and consumption, promoting the minimization of waste from the source and the use of recyclable materials, reducing the ecological impact of student consumption habits. Finally, by decreasing pressure on landfills and avoiding practices such as waste burning, the intervention also supports SDG 13: Climate action, mitigating greenhouse gas emissions and strengthening environmental resilience, [5], [6, 8], [11].

From an academic and methodological perspective, the study offers a valuable contribution to environmental education by articulating curricular content with the daily practice of students, incorporating the circular economy approach and individual and collective responsibility in waste management. At the same time, it is expected that the results obtained will serve as a basis for proposing recommendations that can be transferred to other educational institutions in the Andean region and at the national level, contributing to the strengthening of evidence-based decisions and the design of public policies aimed at the comprehensive management of this waste, [5, 8].

### 1.1 Solid waste

Solid waste is understood as any object, material, substance or element derived from the use or consumption of a good or service, which its generator disposes of, or has the intention or obligation to do so, and must be managed with priority in its recovery and in a residual manner. . Such waste includes all matter in solid or semi-solid state, as well as liquids or gases stored in containers or tanks intended for disposal, as well as those that cannot

be incorporated into emission and effluent treatment systems, which require safe conditioning prior to final disposal, [12, 13].

### 1.2 Solid waste management

Solid waste management, also called integrated management, is a discipline that encompasses an articulated set of technical, regulatory, financial and planning actions, [3, 4, 8, 10].

This discipline is linked to the regulation of the entire solid waste cycle, which includes its generation, storage, collection, transfer, transport, treatment and final disposal, [8, 9].

Its purpose is to articulate these activities with the principles of public health, economic efficiency, engineering criteria, environmental conservation, aesthetics and other ecological aspects, responding to the demands and expectations of society, [2].

Integrated solid waste management comprises the set of administrative, financial, legal, planning and engineering functions essential to face and solve the problems associated with such waste. Its main purpose is to protect the environment and public health, promote the circular economy and the recovery of waste, [2], [14].

The fundamental principles of this management are, [14].

**Prevention or Minimization:** The primary purpose is to minimize the generation of solid waste as much as possible from its source, this being the most recommended option compared to any other management alternative. This decreases the amount and toxicity of waste. [12,13,14][4]

**Recovery or Recovery:** When prevention in generation is not feasible, priority is given to recovery and recovery, both material and energy, always guaranteeing the protection of health and the preservation of the environment, [12, 13, 14].

**Adequate Final Disposal:** This is the last alternative and must be carried out in environmentally appropriate infrastructures and conditions, [12, 13, 14].

Likewise, integrated management aims to replace the culture of disposal with one that promotes sustainable production and consumption practices, applying a hierarchical strategy that prioritises avoiding, reducing, treating and, ultimately, disposing of waste. It implies a co-responsibility between generators, producers, importers, distributors, consumers and management operators, covering both the public and private sectors, [2], [12, 14].

### 1.3 Peruvian regulations on solid waste management

In Peru, the management and handling of solid waste is mainly governed by Legislative Decree No. 1278, "Law on Integrated Management of Solid Waste (LGIRS)", enacted in 2016, and its amendments, as well as by its regulation, Supreme Decree No. 014-2017-MINAM. This legislation repeals the previous Law No. 27314, General Law on Solid Waste, [12, 13, 14].

It defines the rights, duties, competencies and responsibilities of society as a whole, in order to guarantee solid waste management and handling that is economically viable, safe from a health perspective and environmentally sustainable, [12].

#### 1.4 The 3Rs

The 3Rs constitute a set of practices aimed at reducing the amount and danger of the waste generated as much as possible, promoting responsible consumption habits and a rational use of natural resources, with the purpose of preventing environmental impacts of magnitude, [4].

This strategy is based on Bandura's theory of social learning, which maintains that adopting practices such as waste separation or consumption reduction are the product of the observation, imitation and modeling of responsible environmental behaviors that are disseminated in the family and school environment, through four processes: attention, retention, reproduction and motivation, which are incorporated as a habit. In addition, the 3R strategy is also based on Ajzen's theory of planned behavior, according to this model, a pro-environmental behavior (recycle, reduce, reuse) is predicted by a favorable attitude towards a certain behavior that is aligned with the behavioral control that a person perceives. In the school environment, the 3Rs not only focus on transmitting knowledge of environmental protection, but also focus on modifying attitudes, strengthening behaviors and reinforcing pro-environmental group norms. Specifically, the 3R strategy is determined in, [15], [16], [5, 17].

1. Reduce (Minimization): It represents the fundamental priority in waste management and refers to the action of reducing its generation directly at the source. It involves consuming less and more consciously, seeking to maximize efficiency in the use of materials, [4, 12, 13].

2. Reuse (Material Recovery): It consists of obtaining a benefit from a good, article, element or part of it that is already solid waste, extending its useful life. It is a form of recovery that allows the greatest recovery as it does not require intensive industrial processing, [4, 12, 13].

3. Recycling (Material Recovery): It involves the conversion of solid waste into new products, materials or substances, which can maintain their initial function or acquire a different purpose. The waste is converted into an input for another process or a new product. It is one of the material recovery operations, [4, 12, 13], [4].

Thus, several recent studies have shown the effectiveness of educational programs based on the 3R strategy (reduce, reuse and recycle) as a pedagogical mechanism to significantly improve solid waste management in school contexts, both at the initial levels and in basic and higher education. Research such as that of Arroyo and Condori showed that the incorporation of recreational activities, participatory workshops and awareness campaigns around waste management allows the development of positive attitudes and sustainable practices in primary and secondary school students. Similarly, studies such as that of Cotrina et al. and Fonseca validated that environmental education integrated into the formal curriculum, under a critical and

participatory approach, generates lasting behavioral changes and encourages the appropriation of the environment. In family and community settings, research such as that of Cristancho and Lugo highlights the positive impact of programs that link families with the school in ecological projects, favoring collaborative and contextualized learning. At the university level, Vargas et al. and Musa show that the 3R approach can be institutionalized as part of sustainability policies, achieving not only effective waste reduction, but also an organizational environmental culture. Together, these experiences reinforce the relevance of the 3R educational approach as a proven strategy to strengthen environmental awareness, foster the development of citizenship competencies, and contribute to sustainability goals in education, [15], [16], [17], [18], [19], [20], [21], [22].

## 2. Materials and methods

### 2.1 Research Design

The study was framed in an applied type, with an explanatory level and pre-experimental design. Its purpose was to analyze the impact of an environmental educational program based on the strategy of the 3Rs in the management of solid waste by students. Then, it used a single-group scheme with pre-test and post-test measurement, which made it possible to contrast the levels of waste management before and after the pedagogical intervention.

### 2.2 Participants and context

The entire study was done at the "Ramiro Villaverde Lazo" Secondary Education Institution, located in the city of Huancayo. The population consisted of 299 students in grades 3, 4, and 5. The sample consisted of 169 students. From 3rd grade the sample was 70 students between 14 and 15 years old, for 4th grade it was 57, between 15 and 16 years old and for 5th grade it was 42, between 16 and 17 years old. The pedagogical program called School Ecoaction 3R was applied to them, aimed at strengthening knowledge, attitudes and responsible practices linked to solid waste management.

### 2.3 Educational Program

The pedagogical program implemented was called "School Ecoaction 3R", and was designed with the purpose of promoting active environmental awareness in secondary school students, as well as practical skills for the responsible management of solid waste. The implementation of the program was carried out over six weeks, with a periodicity of two weekly sessions, reaching a total of 12 training sessions of 60 minutes each.

The content of the programmed was structured in four progressive thematic blocks:

Block 1: Reduction (Sessions 1, 2 and 3)

Content aimed at sensitizing students about the importance of avoiding unnecessary waste generation was

addressed. The activities included the analysis of real cases, dynamics of reflection on daily consumption habits, and the elaboration of posters promoting responsible consumption. The students made diagnoses of their own consumption habits through field diaries.

#### Block 2: Reuse (Sessions 4, 5 and 6)

These sessions promoted the reuse of potentially useful materials. Creative reuse workshops were organized (such as the elaboration of tool holders, planters or educational games with recycled material) and the participation of families was encouraged to collect unused objects. Internal eco-creativity competitions were also promoted, with exhibitions of the products made.

#### Block 3: Recycling (Sessions 7, 8 and 9)

In this block, the knowledge and practical application of recycling was worked on. Students were trained in the correct classification of waste, learned to identify the types of recyclable materials and participated in the organization of collection points in the classroom. Likewise, representatives of local recyclers were invited to give testimonial talks, strengthening the school community link.

#### Block 4: Consolidation (Sessions 10, 11 and 12)

The final sessions were aimed at integrating the lessons learned. Group projects called "My Sustainable Classroom" were implemented, in which students proposed concrete actions to reduce, reuse and recycle within the school environment. Self-evaluations and co-evaluations were also applied, as well as closure dynamics that allowed the impact of the program to be assessed.

### **Model of the sessions applied: Block 3: Recycling – Session 8 (60 minutes)**

Topic: Correct classification of waste and organization of the collection point in the classroom.

Training purpose: To strengthen practical skills to segregate and recycle solid waste in the school context.

#### Objective of the session

At the end of the session, the students correctly classify solid waste (according to its type) and organize a collection point in the classroom, establishing basic rules of use and care.

#### Product

–Collection point implemented and labeled in the classroom (containers or differentiated boxes).

–Brief record (group file) with types of waste classified and operating agreements.

#### Materials used

–Clean and safe waste (samples): paper/cardboard, plastic bottles, cans, wrappers, simulated organic waste (or images if organic waste is not used), and "non-usable".

–3 to 5 boxes/containers (or bins) for sorting.

–Labels, cardboard, adhesive tape, markers.

–Disposable gloves (optional, recommended) and bags.

–Registration sheets per group (1 sheet).

–Checklist (teacher/observer) for performance evaluation.

#### Start (10 minutes)

#### Activation and framing

–The researchers present 6–8 sample pieces of waste and carry out the short dynamic "Where do I put it?": each

student quickly indicates the correct container (not yet corrected).

–The purpose of the session is to socialize: "to classify with criteria" and "to leave the classroom collection point installed".

–Safety rules are enunciated: careful handling, clean waste, hand hygiene at the end.

–Objective of the beginning (expected achievement): the group understands the practical purpose of the session and recognizes that there is frequent error in classification.

#### Development (40 minutes)

Phase A: Brief explanation and demonstration (15 minutes)

–The basic classification (adaptable to the reality of the school) is explained in simple terms:

–paper/cardboard, 2) plastic, 3) metal, 4) glass (if applicable), 5) organic, 6) non-usable.

–The operational criterion is emphasized: "recyclable" is not only the material, it also influences whether it is clean and dry.

–Guided demonstration: 1 waste per type is taken and its location is justified.

#### Phase B: Teamwork (15 minutes)

–Groups are formed and a set of waste (or cards with waste) is delivered.

–Each group classifies and records in a file: waste → category → short reason

–It is observed and corrected in the process, prioritizing reasoning ("why is it going there").

Phase C: Implementation of the collection point (10 minutes)

–Each group takes on a task:

○ Labelling (name, examples of accepted waste),

○ Strategic location in the classroom,

○ Rules of use (3 minimum rules),

○ Role of managers (weekly shifts).

–The collection point is set up, and the agreements are explained to the whole class.

–Development goals (expected achievements):

○ Students apply segregation criteria with support.

○ The classroom is left with a functional collection point and clear rules.

Closing (10 minutes): Synthesis, verification and commitment

Sharing: each group shares a fixed error ("dirty plastic does not go recycling without cleaning").

A rapid self-assessment (oral or by worksheet) is applied:

–"Today I learned that..." (1 idea), "I commit to..." (1 share).

The next step is agreed: to monitor the use of the collection point during the week (linkable to subsequent sessions).

Objective of closure (expected achievement): consolidate learning and ensure behavioral continuity (commitment).

Evaluation of the session (suggested instrument: checklist)

Observable criteria (Yes/No):

–Correctly identify at least 4 out of 6 types of waste.

–Sorts waste from your equipment without critical errors (or with subsequent correction).

- Argue in a simple way the reason for classification (material/condition).
- Participate in the installation and labeling of the collection point.
- Respects rules of order and safety during handling.
- Record minimum agreements for the operation of the stockpile.

Interpretation: An "expected achievement" was considered when the group correctly classified most of the waste and left the collection point operational with labeling and rules, evidencing procedural learning.

Objectives achieved of the session

In this session, the program managed to operationalize recycling in the classroom, moving from declarative content (knowing what recycling is) to a verifiable action: correct segregation and organization of a collection system, which strengthens the practical dimension of solid waste management (classification, recovery and responsible disposal).

**Methodology used:**

The methodology was active, participatory, and experiential, following the principles of the competency-based approach. Techniques such as project-based learning, case studies, cooperative work and playful dynamics were used. The role of the teacher was that of facilitator, guiding students in the meaningful construction of learning through direct experience.

**2.4 Materials and resources:**

Printed resources (didactic guides, observation sheets, infographics), recyclable resources contributed by students and their families, audiovisual material (educational videos and short environmental films) and recreational spaces in the classroom and schoolyard adapted for practices were used.

Program monitoring and evaluation:

During the application, continuous monitoring was carried out through checklists and anecdotal records, as well as feedback sessions at the end of each block. At the end of the intervention, the questionnaire with a Likert scale was administered again, to contrast the results of the pre-test and the post-test, which made it possible to evaluate the impact of the program in the areas of knowledge, attitudes and practices related to solid waste management.

In short, the "3R School Eco-Action" program was a comprehensive pedagogical strategy that combined theory, practice, and reflection to transform students' environmental behaviors and empower them as active agents of change in their school community.

**2.5 Data collection technique and instrument**

The observation technique was used. The instrument was a checklist with a scale of 3 categories (Yes, sometimes, no), specifically designed to measure the level of solid waste management in students. This instrument considered indicators linked to the three dimensions of the 3R strategy, evaluating cognitive (knowledge), attitudinal (assessment) and behavioral (practices) aspects.

The checklist was applied two times: before the intervention (pretest) and after the end of the program (post test), with the purpose of identifying the changes generated in the students after the execution of the "3R School Eco-action" program.

**3. Results**

**3.1 Comparison between solid waste management between pre- and post-test**

**Table 1.** Results for solid waste management.

| Level      | Test | Solid waste management |       |
|------------|------|------------------------|-------|
| Inadequate | Pre  | 93                     | 55.0% |
|            | Post | 0                      | 0.0%  |
| Regular    | Pre  | 76                     | 45.0% |
|            | Post | 16                     | 9.5%  |
| Suitable   | Pre  | 0                      | 0.0%  |
|            | Post | 153                    | 90.5% |

According to the results of the Table 1, in the pre-test it was evidenced that 55.0% were rated with an inadequate level, on the contrary in the post-test an improvement was shown, since this level was reduced to 0.0%, while the adequate level increased from 0.0% to 90.5%, achieving that almost all students developed a greater awareness in solid waste management. This result indicates that the educational intervention generated a significantly positive effect on the acquisition of skills and the adoption of favorable attitudes towards waste management, confirming the effectiveness of active pedagogical strategies based on the 3R approach. The progression observed responds to a process of internalization of environmental content and the systematic practice of sustainable habits during the program sessions.

**Table 2.** Results for prevention or minimization

| Level      | Test | Prevention or minimization |       |
|------------|------|----------------------------|-------|
| Inadequate | Pre  | 108                        | 63.9% |
|            | Post | 0                          | 0.0%  |
| Regular    | Pre  | 61                         | 36.1% |
|            | Post | 28                         | 16.6% |
| Suitable   | Pre  | 0                          | 0.0%  |
|            | Post | 141                        | 83.4% |

In the Table 2, for the prevention dimension, an improvement from 0.0% to 83.4% was obtained between the pre- and post-test for the appropriate level, this improvement recorded reflects that the strategies used, such as the analysis of consumption habits and the elaboration of awareness posters, allowed a reflexive appropriation of the actions aimed at minimizing the environmental impact from school and home. So, the remarkable progress of the students shows that the methods employed, such as studying how people use things and creating informational posters, led to a thoughtful adoption of actions aimed at reducing the ecological footprint at school and at home

**Table 3.** Results for assessment or recovery

| Level      | Test | Assessment or recovery |       |
|------------|------|------------------------|-------|
| Inadequate | Pre  | 151                    | 89.3% |
|            | Post | 0                      | 0.0%  |
| Regular    | Pre  | 18                     | 10.7% |
|            | Post | 25                     | 14.8% |
| Suitable   | Pre  | 0                      | 0.0%  |
|            | Post | 144                    | 85.2% |

The results of Table 3, for the assessment dimension, in the pre-test, 89.3% of the students showed an inadequate level; while in the post-test the figure was reduced to 0.0%, becoming 85.2% at the appropriate level. The findings show that workshops for creative reuse, along with school exhibitions and competitions for ecological creativity, successfully motivated the transformation of waste into valuable or artistic items. This breakthrough shows the improvement of ecological skills in students, along with their ability to change the view of leftovers, considering them as possibilities for recycling.

**Table 4.** Results for final disposal

| Level      | Test | Final Disposition |       |
|------------|------|-------------------|-------|
| Inadequate | Pre  | 48                | 28.4% |
|            | Post | 0                 | 0.0%  |
| Regular    | Pre  | 115               | 68.0% |
|            | Post | 32                | 18.9% |
| Suitable   | Pre  | 6                 | 3.6%  |
|            | Post | 137               | 81.1% |

Regarding the final disposal results, shown in the Table 4, the pre-test 28.4% were classified as inadequate, in the post-test this figure was reduced to 0.0%; as for the adequate level it went from 0.0% to 81.1% between the pre- and post-test. These results indicate that accurate separation of garbage, appropriate application of different bins, and understanding the results of careless disposal were reinforced lessons. In terms of teaching, it was verified that the course offered theoretical understanding and real altered behaviors and methods within the school environment. From the global comparative analysis, it is observed that there were improvements between the pre- and post-test, since the students in more than 80% for the dimensions and variables showed notable improvements, going from an inadequate level to an adequate level, this shows that the environmental pedagogical strategy "School Ecoaction 3R", was effective in increasing environmental awareness; specifically on solid waste management.

### 3.2 Inferential analysis of the results

**Table 5.** Testing Ranges for Solid Waste Management Dimensions

|                                     | Ranks           | N   | Average Range |
|-------------------------------------|-----------------|-----|---------------|
| Prevention or minimization (post) - | Negative Ranges | 0   | 0.00          |
|                                     | Positive Ranges | 169 | 85.00         |
| Prevention or minimization (pre)    | Draws           | 0   |               |
|                                     | Total           | 169 |               |

|  |                 |     |       |
|--|-----------------|-----|-------|
| Assessment or recovery (post) -                    | Negative Ranges | 0   | 0.00  |
|  | Positive Ranges | 169 | 85.00 |
| Assessment or recovery (pre)                       | Draws           | 0   |       |
|  | Total           | 169 |       |
| Final Disposition (post) - Final Disposition (pre) | Negative Ranges | 4   | 4.50  |
|  | Positive Ranges | 162 | 85.45 |
| Final Disposition (pre)                            | Draws           | 3   |       |
|  | Total           | 169 |       |

Table 5 reveals that, in the three dimensions evaluated (prevention or minimization, assessment or recovery, and final disposal), most students showed significant improvements in the post-test, compared to the pre-test. In the cases of prevention or minimization and assessment or recovery, the 169 students (100%) obtained positive ranks, indicating that all experienced an improvement in their behaviours and attitudes related to waste management. This shows a pedagogically relevant modification in their environmental awareness, favoured by the practical sessions of the program.

Regarding the final disposal dimension, 162 positive ranges (95.8%), 4 negative ranges (2.4%) and 3 ties (1.8%) were identified. Although there was a small group that showed no improvement or had a slight setback, the overwhelming majority achieved a better performance, which validates in general terms the effectiveness of the final disposal component within the program, although it also suggests that this dimension may require further reinforcement in future applications.

**Table 6.** Testing Ranges for Solid Waste Management

|                                   | Ranks     | N   | Average Range |
|-----------------------------------|-----------|-----|---------------|
| Solid waste management (post-pre) | Negatives | 0   | 0.00          |
|                                   | Positives | 169 | 85.00         |
|                                   | Draws     | 0   |               |
|                                   | Total     | 169 |               |

In the Table 6, corresponding to the global variable "solid waste management", 100% of the students obtained positive ranks, which indicates that all improved their overall performance after the intervention, without exception or setback.

**Table 7.** Z-Test for Solid Waste Handling Dimensions

| Dimension                             | Z         | P-Value |
|---------------------------------------|-----------|---------|
| Prevention or minimization (post-pre) | -11,292** | 0.000   |
| Assessment or recovery (post-pre)     | -11,291** | 0.000   |
| Final Disposition (post-pre)          | -11,158** | 0.000   |

Note. \*\*Significant at 1%.

As for the values obtained in the Z tests for each dimension and for the general variable, they are highly significant. In Table 7, the dimensions of prevention or minimization ( $Z = -11.292$ ,  $p = 0.000$ ), assessment or recovery ( $Z = -11.291$ ,  $p = 0.000$ ) and final disposal ( $Z = -11.158$ ,  $p = 0.000$ ) present negative Z values with a significance level of less than 0.05, specifically  $p = 0.000$ , which indicates that there are statistically significant

differences between the scores obtained in the pre- and post-test.

**Table 8.** Z-Test for Solid Waste Management

| Variables                         | Z         | P-Value |
|-----------------------------------|-----------|---------|
| Solid waste management (post-pre) | -11,278** | 0.000   |

*Note.* \*\*Significant at 1%.

In the Table 8, the analysis of the global variable "solid waste management" ( $Z = -11.278$ ,  $p = 0.000$ ) reaffirms this finding, concluding that the implementation of the program produced a significant positive impact on the environmental behavior of the students.

The results corroborate, through a rigorous statistical approach and a structured pedagogical implementation, the remarkable effectiveness of the "School Ecoaction 3R" program as a transformative strategy in the environmental education of secondary school students. The evolution of performance levels from the pre-test to the post-test, with 90.5% of students achieving adequate solid waste management and the total eradication of the inadequate level, constitutes an empirically relevant finding, which reinforces the statements of authors such as Arroyo and Condori, who argue that the incorporation of playful and participatory programs focused on the 3Rs enhances the appropriation of sustainable practices by students, [15], [16].

The study is also closely aligned with what Cotrina et al. and Fonseca, who argue that the critical integration of environmental education into the formal curriculum has a significant impact on behavior modification. Indeed, the program applied not only offered theoretical content, but also articulated experiential activities such as creative reuse workshops, waste sorting days and school recycling campaigns, allowing a deep internalization of the principles of the circular economy. Such a methodological design favored the transition from declarative environmental education to transformative education, focused on doing, reflecting and collaborating, key principles for the development of citizenship competencies, as pointed out by Lema et al. and ECLAC, [17], [18], [8], [9].

Likewise, the significant improvement observed in the three dimensions of solid waste management (prevention or minimization, valuation or recovery and final disposal) is supported by studies such as those by Vargas et al. and Musa, Cristancho and Lugo, who demonstrated that institutionalized programs based on the 3Rs not only improve individual performance, but also foster an environmentally committed organizational culture. Although these studies were developed in university contexts, the results of this work suggest that this approach can also be highly effective in basic education, if adapted through didactic strategies appropriate to the age and sociocultural context of the students. In addition, it should be noted that the involvement of families in ecological school projects increases the effectiveness of environmental programs, which suggests that environmental education, in order to be sustainable, must include inter-institutional and community components, [19], [20], [21], [22].

## 4. Conclusions

The implementation of the "3R School Eco-Action" program as an environmental education strategy was effective in improving solid waste management in 3rd, 4th and 5th grade students of the secondary level of the I.E. "Ramiro Villaverde Lazo". This experiential approach, collaborative work, and the integration of practical content around the 3Rs managed to consolidate significant and sustainable learning. The favorable change in attitudes and behaviors regarding solid waste is not only statistically measurable but also evidenced in the environmental culture generated in the classroom, showing that the educational intervention promoted not only knowledge, but also responsible action in students.

On the other hand, the findings strengthen the available evidence on the viability of educational programs based on the 3Rs as a tool to achieve the SDGs, especially those related to quality education (SDG 4), sustainable cities (SDG 11), responsible consumption (SDG 12) and climate action (SDG 13), as proposed by Awino and Apit, Padli et al. and ECLAC, [5], [8], [11].

Among the main limitations of the study is the restricted contextual scope, since the intervention was applied in a single educational center in the city of Huancayo, limiting the generalization of the data to other sociocultural realities. Likewise, the implementation time (six weeks) was short to assess the sustainability of the long-term behavioral changes. On the other hand, the perception of teachers, families and authorities was not considered, which would have enriched the comprehensive understanding of the impact of the program. In view of this, it is recommended that future research expand the geographical and population scope of the study, incorporating institutions from different levels and regions of the country. It would also be pertinent to develop longitudinal evaluations that analyze the permanence of environmental learning over time.

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