

Recycling Domino as a Didactic Strategy for Learning Integrated Urban Waste Management

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Abstract

This article aims to propose the recycling domino as a didactic strategy designed to promote meaningful learning of the integral management of urban waste, through the design, development, and implementation of an educational game with 33 students from a public educational institution in Valledupar, Colombia. The research was conducted under a qualitative approach, with an action research design and a descriptive scope. The results revealed an initially low conceptual appropriation, which significantly improved after the participatory workshop and the implementation of the recycling domino, highlighting its effectiveness as an innovative didactic resource to strengthen environmental competencies. It is concluded that this playful strategy facilitates comprehensive learning and can be replicated in other educational institutions seeking to promote sustainable practices.

Keywords: didactic strategies, integral management of urban waste, environmental education, educational games, meaningful learning.

1. INTRODUCTION

The comprehensive management of urban solid waste is one of the main environmental challenges of the twenty-first century, due to population growth, consumption habits, and limited citizen awareness of sustainable practices (UN, 2020; OECD, 2016; World Bank, 2020).

In this regard, the UN Secretary-General (2022) declared that "Humanity is treating our planet like a garbage dump, we are destroying our only home" (p. 1). In this sense, the aforementioned organization, based on figures from the World Bank (WB) and the United Nations Environment Program (UNEP), highlighted that 2000 million tons of urban solid waste are produced annually worldwide, of which approximately 45% is not properly managed. This situation is alarming and requires the collaboration of industry, governments and civil society to achieve more responsible management.

In the Colombian context, this problem acquires particular relevance, since according to the National Planning Department (DNP, 2018), each inhabitant generates an average of 0.79 kg of waste per day, of

which less than 20% receives adequate treatment (DANE, 2020), affecting urban and rural ecosystems (Andrade, 2017).

Various studies have shown that the lack of environmental education and the limited incorporation of innovative teaching strategies in educational institutions influence the low appropriation of practices related to the separation, reduction and use of waste (Pérez-Arriaga, Acosta-Flores, Maldonado González, & Acuña Bustamante, 2022); Redalyc, 2020; Barreiro & Castro, 2023), which reduces the development of practical skills related to the separation, reduction and use of waste.

This panorama reveals the need to strengthen the formation of environmental skills from education, at all levels, to consolidate citizens committed to sustainability, in line with the recommendations of UNESCO (2020) and UNEP to advance towards the Sustainable Development Goals.

In this sense, the institutional diagnosis carried out in an official establishment in Valledupar, Cesar; evidenced the need to improve the responsible management of solid waste (SRM) among its students. Although the school leads the mandatory transversal project on environmental protection, ecology and preservation of natural resources Ministry of Environment and Sustainable Development - MADS (2017), through initiatives such as eco art fairs, eco mimes, environment day days with songs and poetry, and plays staged with sixth grade children, the challenges persist.

Students at this level have also produced short videos and workshops to raise awareness among their classmates, and even the "Day of the No Caneca" is projected to reduce waste in the school day. However, the project leader recognizes that, despite the multiplicity of activities, the environmental problem continues, there is more awareness than true awareness, which reflects a lack of deep-rooted citizen awareness.

This scenario is aggravated by the observation in room 6°08, selected for this research, of a greater amount of waste on the floor compared to other groups, a paradoxical situation given that these students are the ones who lead the environmental awareness actions in the institution. This reveals a weak understanding of integrated solid waste management (GIRS) that could negatively impact both the school environment and their holistic learning.

This problem coincides with research such as that of López and Barreto (2019) and Rivera & Salazar (2021), which highlight the gap between superficial awareness and true environmental awareness in school contexts.

In this context, the general objective was to propose the recycling domino as a didactic strategy to promote meaningful learning of the integral management of urban waste. To this end, three specific objectives were defined: (a) to design a recycling domino game as a pedagogical tool, (b) to develop a participatory workshop to train students in waste management using this resource, and (c) to implement recycling dominoes as a didactic strategy to consolidate significant learning.

The pedagogical support is found in the contributions of Piaget (1972) and Ausubel (2002), who underline the value of play and meaningful learning to mobilize cognitive schemes, as well as in Vygotsky (1979), Johnson and Johnson (2017) and Hinojosa and Torres (2020), who highlight cooperative learning as the basis for transformative processes.

From the methodological point of view, a qualitative approach was chosen under an action-participatory research (PAR) design (Kemmis & McTaggart, 1988; Luna & Gómez, 2021), allowing students and researchers to build knowledge and generate tangible changes. This study sought to respond to the urgent need to articulate pedagogical proposals that motivate active participation and promote responsible attitudes towards the environment, adding evidence to the corpus of research on environmental gamification (Pérez-Arriaga et al. 2022; Chiquito Chilan, 2022).

2. THEORETICAL CONSIDERATIONS

• Meaningful learning

Significant learning, proposed by Ausubel (2002), supports the importance of new knowledge being related in a substantial and non-arbitrary way to what the student already knows, facilitating its retention and

applicability. This approach is complemented by the social constructivism of Vygotsky (1979), who emphasizes the role of sociocultural interaction and the scaffolding provided by the teacher or mediators for cognitive development. In today's educational environment, it is recognized that learning should not only focus on the transmission of content, but also on the creation of experiences that actively involve the student, promote critical thinking, and stimulate collaborative problem-solving (Hernández, Fernández, & Baptista, 2014; Tigse Parreño, 2019; Ortega & Sánchez, 2022).

- **Didactic strategy**

Authors such as Piaget (1972) have highlighted the value of play in cognitive processes, stating that it constitutes a space of trial and error where mental schemes are elaborated that are later consolidated. In environmental education, the use of games as a didactic strategy has proven to be effective in strengthening pro-environmental attitudes and responsible habits, allowing students to experience simulated situations that help them understand the complexity of ecological problems (Pérez-Arriaga et al., 2022; Redalyc, 2020; Chiquito Chilan, 2022); López & Rivera, 2019).

- **Comprehensive solid waste management**

On the other hand, the integrated management of solid waste has positioned itself as a priority on global agendas. The UN (2015) through the SDGs urges the implementation of sustainable practices that ensure resilient communities.

In Colombia, the National Policy for Integrated Solid Waste Management (PNGIRS) establishes guidelines for educational institutions to promote a culture of use and the circular economy (MADS, 2019). However, local studies (Centenero de Arce, Martínez Orenes, & Guinea Serrano, 2021; Acosta Flores, Maldonado González, Argüa Bustamante, & Pérez Arriaga, 2022) warn that there are still gaps in institutional environmental training, evidencing the need to innovate in teaching methodologies.

- **The Recycling Domain**

Recent research agrees that games, such as didactic dominoes, enhance active learning, as they require the student to apply concepts, solve problems, and collaborate with their peers (Pérez-Arriaga et al. 2022; Pinto & Rojas, 2022). This is articulated with the approaches of Johnson and Johnson (2017), who highlight the importance of cooperative learning in the construction of lasting knowledge. Thus, the application of playful strategies for teaching waste management can become a driver of educational and social change (OECD, 2016; UNESCO, 2020).

3. STUDY METHODOLOGY

This research was framed in a qualitative approach, under the design of action-participation research (PAR), an ideal method to generate reflective and transformative processes in real educational contexts (Kemmis & McTaggart, 1988; Sarmiento & Vega, 2018). According to Hernández et al. (2014), PAR allows researchers and participants to reconstruct knowledge while identifying and addressing problems that directly affect them.

The population was made up of sixth-grade students from an official educational establishment in the municipality of Valledupar, Colombia. We worked with a focus group of 33 students, selected for accessibility, who participated in all phases of the project.

The methodological process contemplated three moments: A. Initial diagnosis, through participant observation and group interviews, to explore previous knowledge and perceptions about waste management.

B. Design and application of a participatory workshop, aimed at introducing the concepts of integrated urban waste management, supported by collaborative dynamics. C. Implementation of the didactic game "Recycling Dominoes", designed by the authors based on the contents discussed, to consolidate learning in a playful way.

Qualitative data were collected through field notes, photographic records, and response categorization matrices during group discussions, which allowed identifying changes in discourse and attitudes towards environmental issues.

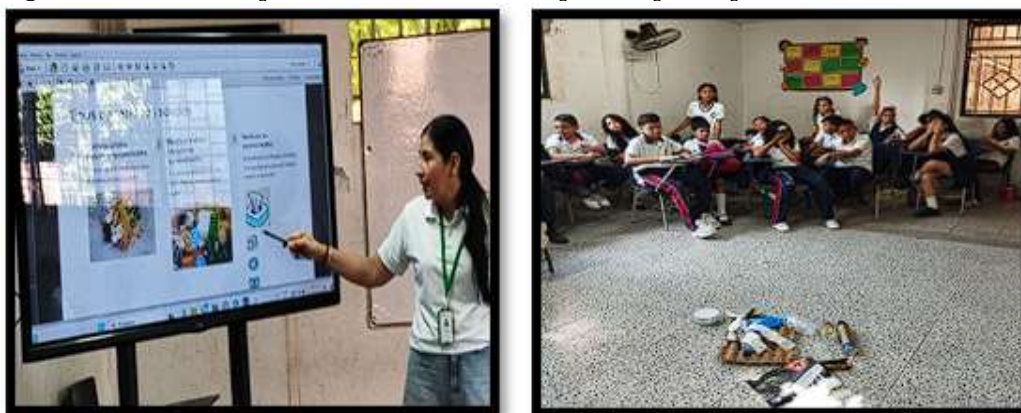
4. RESULTS

The diagnostic process confirmed previous findings in the literature that point to the persistence of conceptual gaps in higher education on environmental issues (Acosta-Flores et al., 2022); Centenero de Arce, Martínez Orenes, and Guinea Serrano (2021). During the first sessions, students demonstrated a lack of regulatory and technical knowledge: for example, 65% did not identify the official color code for separation in Colombia, in line with data from MADS (2019) that show the low level of citizen appropriation of such regulations.

When developing the participatory workshop, discursive transformations were observed that coincide with the effectiveness of dialogic strategies pointed out by Tigse Parreño (2019) and Salinas and Muñoz (2021), who argue that group debate and the collective construction of knowledge promote attitudinal changes. Expressions such as *"I didn't know that a battery could contaminate so many liters of water"* or *"I'm going to talk to my family so that we can separate waste well"* illustrate the transition from initial indifference to personal commitment, a process that Acosta-Flores et al. (2022) also reported in similar experiences of educational environmental education. Most of the students had prior knowledge of waste separation, but there was confusion about the classification of solid waste, especially hazardous waste.

During the theoretical presentation, the students showed interest when they were explained the classification of waste into organic and inorganic, usable and non-usable, as well as the negative effects produced by poor MRS. The environmental impact caused by the lack of recycling was highlighted and the importance of applying the 3Rs rule: Reduce, Reuse and Recycle was presented. Students actively participated, asking questions about how to improve recycling at home. This evidences the conceptual appropriation and the beginning of sustainable practices that consolidate an environmental culture (Rendón Navarrete, Rendon Navarrete, Choez Chillogallo, & Chiquito Chilan, 2024).

Figure 1: Theoretical presentation of the concepts and participation of the students



Note. The figure represents the interaction between the participants at the time of carrying out the theoretical presentation.

In the practical activity, the students were divided into groups and classified waste into different containers in green, red, white and black colors MADS (2019). Despite some mistakes at first, most of the students managed to sort the waste correctly. This activity generated an interesting discussion in the participating students about what materials could be recycled and what their impact on the environment was; in such a way that it facilitated the learning process and environmental awareness (Blanco, Ramírez, & Castillo, 2021) (see Figure 2).

Figure 2: Development of the practical activity



Note. The images show the development of the practical activity of the workshop on sustainable solid waste management.

After this activity, the proposed recycling domino game with its respective rules was announced.

Figure 3: Explanation of how the recycling domino is played



Note. The image shows one of the researchers explaining each of the games and what are the rules that must be taken into account during the development of these.

- **Recycling Dominoes Set**

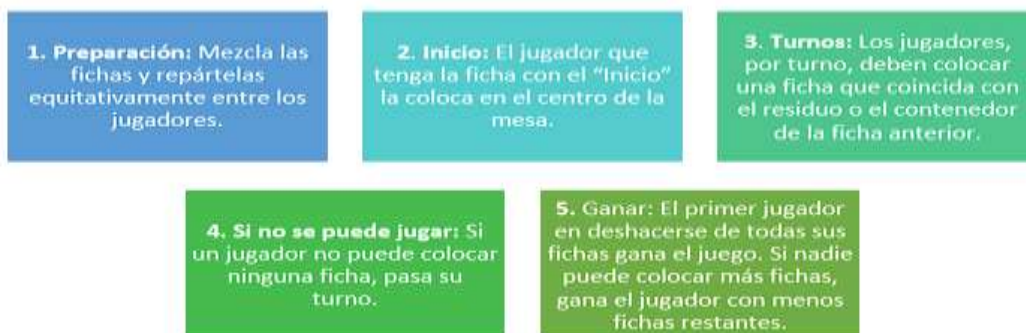
The objective of the recycling Dominoes game was to motivate students to relate waste to its corresponding containers in a competitive and cooperative way; in such a way, learning about the integral management of urban waste.

The recycling domino set is made up of 26 wooden tiles, each tile has two halves:

- A. One half shows the color corresponding to the type of solid waste (red, green, white, or black).
- B. The other half shows the associated residue.

The recycling domino game features the following rules in Figure 4.

Figure 4: Rules of the Recycling Domino Game



Note. The figure shows the 5 rules that players should keep in mind when starting the game of dominoes.

In original Spanish language

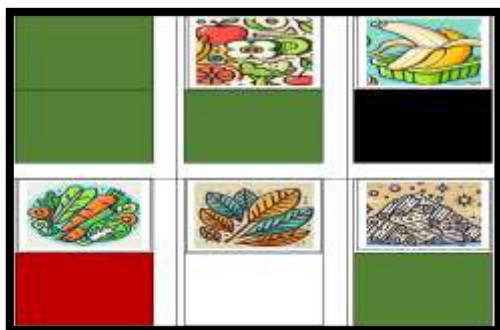
Consequently, the 26 wooden worksheets were specifically designed with images related to inorganic and organic solid waste, usable and non-usable. On one side of the cards, combinations of images representing different types of SR are printed. Shown below in Figures 5,6,7 and 8 are the 6 tiles combined each according to the type of SR that were used in the game of dominoes.

Figure 5: Chips combined with usable inorganic solid waste



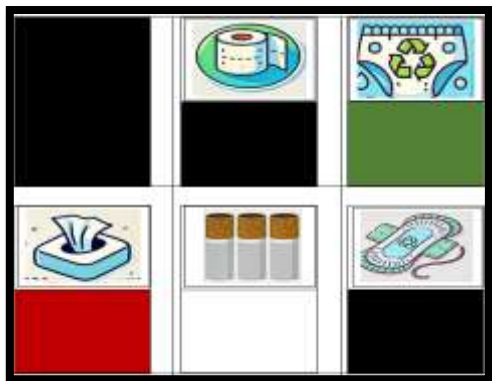
Note. The image shows six files related to usable inorganic solid waste.

Figure 6: Chips combined with usable organic solid waste



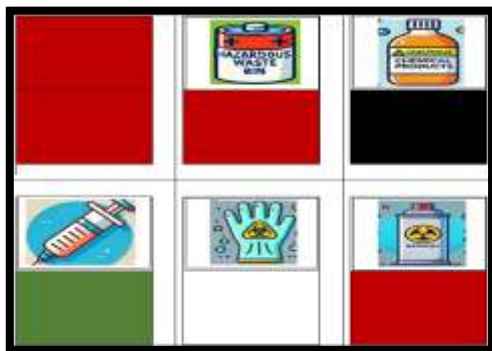
Note. The image shows six files related to usable organic solid waste.

Figure 7: Chips combined with non-usable solid waste



Note. The image shows six files related to non-usable solid waste.

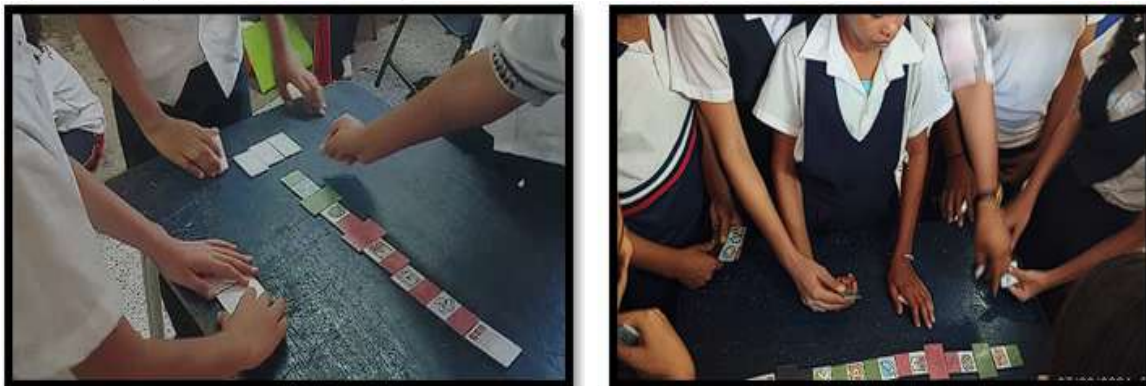
Figure 8: Files combined with hazardous waste



Note. The image shows six files related to hazardous waste.

Significant learning is evidenced in the development of the application of the recycling domino game, since the students were able to correctly identify and classify waste according to its type. In addition, it was observed that, through the playfulness of the game, the students reinforced the concepts learned in a dynamic and entertaining way. The game promoted teamwork and discussion among the participants, which facilitated the learning process.

Figure 1: Application of Recycling Domino Game



Note. The image represents the development of the application of the recyclable domino game by the participants.

The implementation of recycling dominoes generated a high level of involvement. The participants highlighted the "dynamic" and "fun" nature of the activity, in line with what was indicated by Pérez-Arriaga et al. (2022), who documented that the didactic game not only increases conceptual retention, but also improves the perception of learning as a positive experience. Likewise, 80% of the students expressed in the final reflections that this type of dynamic helped them to "remember more clearly the categories of residues", validating Piaget's (1972) approaches to play as a mechanism for assimilating new mental schemes.

For their part, Pérez-Arriaga et al., 2022 and Chiquito Chilan, 2022) highlight that gamification in environmental contexts encourages the internalization of pro-environmental values. This was evidenced in student phrases such as *"now I care more about not throwing plastic where it is not"*, which reflect the emergence of critical environmental awareness, as promoted by UNESCO (2020) in its roadmap for Education for Sustainable Development.

The triangulation of qualitative data collected through participant observation, the analysis of the debates in the workshop and the perceptions about the game consolidated categories such as "collaborative learning", "normative appropriation" and "motivation for change", coinciding with Hernández et al. (2014), who highlight that action and participation research approaches not only diagnose, but transform educational realities through the active involvement of the actors.

Table 1 Triangulation of qualitative findings

Source of information	Emerging categories	Authors supporting similar findings
Participant observation	Low initial appropriation, progressive curiosity	Acosta-Flores et al. (2022); Centenero de Arce, Martínez Orenes, and Guinea Serrano (2021)
Participatory workshop	Collective awareness, normative awareness	Salinas y Muñoz (2021); Tigse Parreño (2019)
Recycling dominoes game	Practical understanding, conceptual retention	Piaget (1972); Pérez-Arriaga et al. 2022; Pérez-Arriaga et al. (2022).
Final Group Reflections	Personal and social commitment, pro-environmental attitudes	Chiquito Chilan (2022); UNESCO (2020); Hernández et al. (2014)

In this way, it is corroborated that the use of recycling dominoes as a didactic strategy not only facilitated the meaningful learning of concepts related to integrated waste management, but also activated metacognitive and evaluative processes in students, as Johnson and Johnson (2017) defend with respect to cooperative environments, and Ausubel (2002) in relation to learning anchored to meaningful experiences.

The results obtained confirm the effectiveness of the didactic game as a pedagogical tool to consolidate significant learning around the integrated management of urban waste. When comparing the findings with previous research, Pérez-Arriaga et al. (2022) and Redalyc (2020) corroborate the findings, who highlight that university students have important conceptual gaps in environmental regulations and waste management, a situation that is reproduced in students of the Bachelor's Degree in Natural Sciences and Environmental Education program at the UPC.

The application of the participatory workshop and, especially, the implementation of the recycling dominoes, activated reflective and collaborative processes among the students. This coincides with Tigse Parreño (2019), who stresses that learning is most effective when it takes place in social contexts

that favor interaction, with Vygotsky (1979), who argues that the scaffolding provided by the environment allows for the construction of shared meanings, and with the contributions of González and Pérez (2020), who in their research highlighted the positive impact that environmental educational strategies have on transforming practices and consolidating learning sustainable in educational institutions.

Authors such as Hernández et al. (2014) and Kemmis & McTaggart (1988) argue that action-participation research generates real changes in the contexts studied, by involving actors as co-researchers. This study exemplifies this potential, since by involving students in playful dynamics and critical debates, it was possible to move from diagnosis to the transformation of attitudes, observing greater regulatory appropriation and willingness to replicate sustainable practices in their family environments, as proposed by Acosta-Flores et al. (2022) in the framework of transformative environmental education.

The increase in motivation and enjoyment of learning observed during the use of recycling dominoes is supported by Piaget (1972), who considers that play is a natural way to build cognitive structures, and by Ausubel (2002), who emphasizes the importance of significant prior organizers, here materialized in the workshop and in the rules of the game. This type of playful strategy is particularly pertinent in addressing environmental issues, which require an evaluative and affective component to consolidate themselves as permanent practices (UNESCO, 2020; UN, 2015).

For their part, Johnson & Johnson (2017) point out that cooperative learning not only increases academic performance, but also improves the perception of the other as an ally in the cognitive process. This dynamic was evident in the game sessions, where students collaborated to correctly identify the domino pieces, discuss mistakes, and celebrate successes, consolidating a climate of trust that, according to (Centenero de Arce, Martínez Orenes, & Guinea Serrano, 2021) is essential for critical educational processes.

Finally, the results dialogue with the global approach proposed by the OECD (2016) and the national guidelines of the PNGIRS (MADS, 2018), which call for strengthening environmental citizenship competencies from educational spaces, promoting daily practices that contribute to sustainability. Thus, the research not only contributes to the local academic community, but is also part of the global effort to meet the SDGs related to sustainable cities and responsible consumption (UN, 2015).

5. CONCLUSIONS

The use of recycling dominoes as a didactic strategy within a qualitative methodology based on action and participation research proved to be effective in promoting meaningful learning about the integral management of urban waste in elementary school students of an official educational establishment in the municipality of Valledupar, Colombia. This resource allowed not only to clarify technical concepts such as waste classification and current regulations, but also to arouse pro-environmental attitudes and personal commitments to sustainability.

The articulation of participatory workshops with games of rules evidenced the value of playful strategies to energize the classroom, increase motivation and generate spaces for critical reflection, coinciding with the postulates of Piaget (1972), Ausubel (2002) and Tigse Parreño (2019). Likewise, it was found that the action-participation research approach enhances the appropriation of learning by directly involving students in the diagnosis and search for solutions.

It is recommended to replicate this experience in other educational establishments that seek to strengthen environmental competencies, as well as to continue exploring didactic methodologies that integrate play and active participation to address complex socio-environmental problems.

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