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Exploring Playful and Technological Strategies: Insights for Developing Games and Educational Applications About Recycling for Children

Abstract *As human behavior becomes a significant factor in the impact of waste disposal on nature It is crucial to explore strategies to engage the population on this topic and encourage a more sustainable relationship with the environment. The present review focuses on mapping and understanding relevant aspects provided by the literature from January 1, 2020, to May 10, 2024, for the production and use of game software and applications to teach children about environmental preservation and recycling principles. The results highlight the importance of environmental awareness from early childhood, emphasizing the role of playful and technological education in promoting sustainable practices among children.*

Keywords Games, Educational Applications, Recycling, Children.

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Explorando Estratégias Lúdicas e Tecnológicas: Perspectivas para o Desenvolvimento de Jogos e Aplicativos Educativos sobre Reciclagem para Crianças

Resumo Conforme o comportamento humano torna-se um fator significativo no impacto do descarte de resíduos na natureza, é crucial explorar estratégias para engajar a população nesse tema e incentivar uma relação mais sustentável com o meio ambiente. A presente revisão foca no mapeamento e compreensão dos aspectos relevantes fornecidos pela literatura de 1º de janeiro de 2020 a 10 de maio de 2024, para a produção e uso de softwares e aplicativos de jogos voltados para ensinar crianças sobre preservação ambiental e princípios de reciclagem. Os resultados destacam a importância da conscientização ambiental desde a infância, enfatizando o papel da educação lúdica e tecnológica na promoção de práticas sustentáveis entre as crianças.

Palavras-chave Jogos, Aplicativos Educacionais, Reciclagem, Crianças.

Explorando Estrategias Lúdicas y Tecnológicas: Perspectivas para el Desarrollo de Juegos y Aplicaciones Educativas sobre Reciclaje para Niños

Resumen A medida que el comportamiento humano se convierte en un factor significativo en el impacto de la eliminación de residuos en la naturaleza, es crucial explorar estrategias para involucrar a la población en este tema y fomentar una relación más sostenible con el medio ambiente. La presente revisión se centra en el mapeo y la comprensión de aspectos relevantes proporcionados por la literatura desde el 1 de enero de 2020 hasta el 10 de mayo de 2024, para la producción y el uso de software y aplicaciones de juegos dirigidos a enseñar a los niños sobre la preservación ambiental y los principios de reciclaje. Los resultados destacan la importancia de la conciencia ambiental desde la infancia, enfatizando el papel de la educación lúdica y tecnológica en la promoción de prácticas sostenibles entre los niños.

Palabras clave Juegos, Aplicaciones Educativas, Reciclaje, Niños.

Introdução

Human behavior is a significant factor in the impact of waste disposal on nature. This interaction influences the entire ecosystem, especially the marine environment, which faces severe challenges due to the improper disposal of plastic materials (Sheavly e Register, 2007). Improper waste disposal occurs both accidentally and intentionally, necessitating efforts to raise public awareness through educational and preventive measures regarding waste management. It is crucial to explore strategies to engage the population on this topic and encourage a more sustainable relationship with nature (Locritani et al., 2019).

One strategy to promote a healthy interaction with the environment is to provide opportunities and stimuli for the development of environmental awareness from early childhood. This way, new generations can contribute to a more sustainable and sensible future (Pramling Samuelsson, 2011). Preschool is a crucial period in a child's life for cognitive, social, and emotional development. In this context, fostering a responsible and conscious attitude toward waste disposal among children in this formative phase creates solid foundations for sustainability, environmental protection, and social responsibility (Poje, 2024).

In this regard, the use of playful and technological means can be an effective tool to engage and stimulate children's interest in waste recycling, contributing to the mitigation of environmental problems resulting from improper waste disposal (Rossano et al., 2022). Technologies such as electronic games and applications have proven to be important allies in inspiring and motivating users in the field of education and entertainment, especially among the younger audience (Kim et al., 2017).

Thus, this systematic review seeks to identify and synthesize insights on gamified strategies and applications documented in the literature between January 1, 2020, and May 10, 2024, that address waste recycling and can contribute to the creation and development of new technologies in this area.

Methods

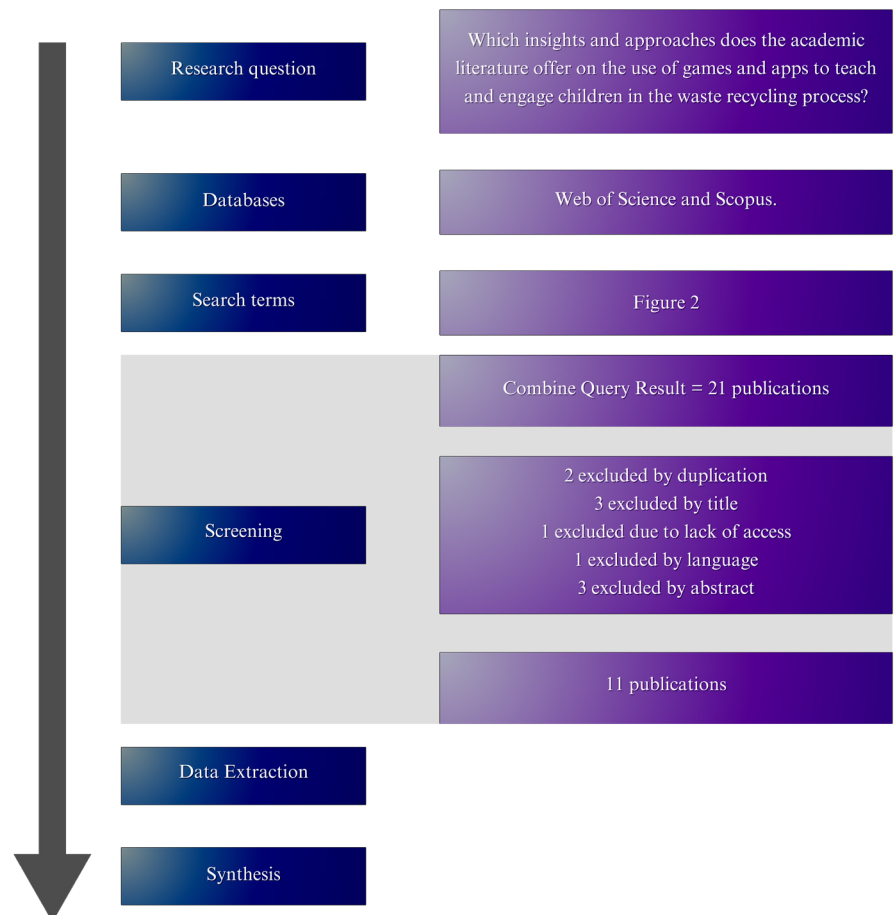
The present review is based on the guidelines of Fink (2010), which comprise three main structures: Literature Sampling, Literature Screening Procedure, and Information Extraction. Utilizing the PRISMA checklist for systematic reviews and meta-analyses (Moher et al., 2009), the review followed a rigorous methodological process.

The research question adopted in this study was as follows: Which insights and approaches does the academic literature offer on the use of games and apps to teach and engage children in the waste recycling process? For the literature review, the databases Web of Science and Scopus were consulted. The specific procedures for literature sampling are described in

greater detail below. The combined query result was 21 publications. After the screening process, 11 publications were selected for data extraction and synthesis of the results.

Figure 1 presents a flowchart detailing the step-by-step adopted procedure, starting with the formulation of the research question and culminating in the synthesis of the results.

Figure 1: Flowchart of the systematic review process
Source: The authors, 2024



Literature Sampling

This study conducted literature sampling in two distinct stages. In the first stage, appropriate keywords related to the research object were defined, along with the selection of the databases to be used. The databases presented in Figure 1 were chosen because they host a wide range of publications on the use of media and its implications on human interactions and the environment. The search was conducted between May 8 and 10, 2024, and was limited to publications from the last 5 years, specifically from January 1, 2020, to May 10, 2024. The scope of the search was restricted to the fields of Title, Abstract, and Keywords.

Initially, the keywords were categorized into five groups according to their meaning (Figure 2). Group A refers to Games and Applications,

Group B to Education, Group C to Recycling, Group D to Waste, and Group E is related to the target age group of this study, which is focused on children. Subsequently, each group of keywords, connected by the OR operator, was searched separately in the search tool of each database. In the second stage, using the “Combine Query” tool, it was possible to merge the five keyword groups into a single search algorithm with the AND operator.

The isolated keyword group searches in the Web of Science database resulted in the following numbers of results for each group: Group A: 2,360,112, Group B: 613,303, Group C: 393,506, Group D: 293,900, and Group E: 825,277. After applying the group combination tool, the final result was 16 publications. In the Scopus database, the isolated searches for each group resulted in the following numbers: Group A: 3,062,002, Group B: 878,509, Group C: 163,796, Group D: 333,701, and Group E: 1,141,114. The combination of keyword groups in this database resulted in 5 articles. Therefore, the total number of articles on the topic eligible for analysis was $16 + 5 = 21$ publications.

The inclusion criteria for the publications were: If the research focus on games, applications and technologies related to recycling education for children; and if the publication is available in English, Portuguese or Spanish. The exclusion criteria adopted were: publication year of the article outside the scope defined for the research; duplicate occurrences; title not corresponding to the topic addressed; inaccessible text; language outside the defined categories; and abstract not demonstrating relevance to the research question (Figure 3).

Figure 2: Keywords list

Source: The authors, 2024



Figure 3: Detailed criteria for exclusion and inclusion of publications
Source: The authors, 2024



Screening Procedure

The literature screening was conducted practically, following the method outlined by Fink (2010), where inclusion and exclusion criteria were defined in advance of analyzing the 21 articles (see Figure 2). During screening, 2 duplicate articles, 3 publications which, based on their titles, were unrelated to the topic, one inaccessible article, and 1 publication not available in English, Portuguese, or Spanish were identified. This resulted in a total of 14 publications considered eligible for a detailed analysis of their abstracts. However, after evaluation and reading, it was found that 3 of these publications addressed topics completely different from the research objective. Therefore, 11 publications were validated for further in-depth study, as shown in Table 1.

Table 1: Publications eligible for detailed analysis
Source: The authors, 2024

Year	Title
2021	Household Waste Generation: Understanding Family Practices and Challenges in Singapore
2021	PeppeRecycle: Improving Children’s Attitude Toward Recycling by Playing with Social Robot
2021	Plastics as an Educational Resource for Sustainable Development: A Case Study in Ghana
2022	Environmental Education experiences in the Biology cathedra the UCLA agro-industrial engineering
2022	From theory to action: Explaining the process of knowledge attitudes and practices regarding the use and disposal of plastic among school children
2022	Mini-games to Motivate and Engage Users in Learning Recycling Rules
2023	Bottle with a message: The role of story writing as an engagement tool to explore children’s perceptions of marine plastic litter
2023	Improvement impact of nudges incorporated in environmental education on students’ environmental knowledge, attitudes, and behaviors

2023	Nurturing Eco-Consciousness: The Journey of the EcoMorph Guardian in Shaping Tomorrow’s Stewards
2024	Environmental Education on Sustainable Principles in Kindergartens – A Foundation or an Option?
2024	Introducing eco-literacy to early childhood students through digital learning

Data Extraction

After identifying the relevant studies, totaling 11 publications, each of them underwent a thorough examination. This process aimed to interpret and recognize key information such as methods, results, and conclusions. These details were subsequently utilized for analysis and synthesis.

Results

The results section is organized into two parts: Technologies as learning tools and techniques and approaches presented by the reviewed studies. Finally, a summary is provided with insights for creating games and apps to teach recycling to children.

Technologies as Learning Tools

There is evidence that parental behaviors significantly influence children’s attitudes towards recycling practices and environmental preservation (Bandura, 1986). Positive reinforcement from adult family members is a relevant factor in developing strong foundations of knowledge about sustainability and environmental awareness (Salazar et al., 2022).

Technology, through interactive games and applications, can serve as a point of intergenerational connection, amplifying the effects of learning on recycling and environmental preservation (Lankes et al., 2017). Furthermore, technology can act as an effective aid to address any potential lack of knowledge among responsible family members about recycling. It can also help mitigate time constraints and parental distance in reinforcing aspects related to environmental preservation and recycling with children (Kaveri, 2021).

In this regard, the use of technologies such as educational games and apps plays a crucial role in teaching about the recycling process and promoting environmental awareness among children. These playful resources have the ability to make learning about recycling more engaging and accessible (Parejo et al. 2021). It represents an innovative and practical approach to involve children in learning about recycling (Poje et al. 2024).

Techniques and Approaches

A notable example of how technology can be used to promote education and awareness about the impacts of waste on nature is the ReCiBa application (Red de Científicos de la Basura). Used by children, this tool allows them to write stories about the presence of plastic in marine habitats. ReCiBa aims to generate scientific data on the sources, distribution, and impacts of waste on marine life, as well as to stimulate conservation strategies. The application directly engages children in understanding the origins, impacts, and solutions to plastic pollution in the oceans. In this research, children had the opportunity to express their perspectives and feelings regarding plastic pollution, accessing galleries of informative images and videos that highlight the interactions of these residues with humans and animals (Praet et al. 2023).

The use of modern technologies, combined with practical field actions, has proven effective as an approach to teaching and engagement (Parejo et al. 2021). Furthermore, strategies involving group activities, painting, crafts, singing, and other artistic expressions are extremely beneficial for the learning environment (Terán e Giménez, 2022). Tools such as YouTube videos, electronic games, stories, and excursions are particularly effective in introducing eco-literacy to preschool-aged children, with emphasis on four pillars: a) empathy; b) community participation; c) making visible what is observable to children; and d) teaching how not to cause environmental harm (Ninsiana et al., 2024).

Another exemplary project that uses technology to teach and engage children in recycling and environmental preservation is PeppeRecycle. This project involves interaction with a social robot named Pepper, which challenges children in a recycling game. During the game, the robot and children must recognize the material of a waste item and decide which bin it should be discarded into. This is made possible by an image recognition module based on Convolutional Neural Networks (CNN), which allows for waste detection and classification. A human moderator was present to ensure the accuracy of responses, and the robot provides a score feedback at the end of the interaction (Terán e Giménez, 2022).

Gamification and games are highlighted as effective tools in learning sustainability concepts. An example is the “Zero Waste Game” project, which uses an empirical approach to demonstrate to players the amount of plastic waste they produce daily. This study incorporates psychological approaches such as “nudge” and “boost” in promoting sustainable behaviors. Thus, the game experience aims to strengthen personalization and connection with students’ lives, generate empathy, and provide personalized feedback (Kurokawa et al. 2023).

In addition to focusing on interaction and fun, when using technology to engage children in recycling, it is essential to create context throu-

gh multiple tools such as stories, videos, and images, always providing immediate and positive feedback (Ninsiana et al., 2024; Praet et al. 2023). The use of electronic games also proves to be a viable and effective alternative for teaching recycling to young audiences (Rossano et al. 2023).

Considering the projects and initiatives observed in this review, fundamental information and insights can be extracted for the development of games and applications aimed at educating children about recycling and sustainability, as demonstrated in the Table 2.

Table 2: Review Results - Insights on Creating Games and Applications for Teaching Recycling and Sustainability to Children

Source: The authors, 2024

Insights for Creating Games and Apps to Teach Recycling to Children	
1. Incorporate Interaction and Fun	Ensure that the game or tool is interactive and fun to keep children engaged.
2. Use Multiple Tools	Work with varied contexts using stories, videos, and images to enrich the learning experience and make it more engaging.
3. Provide Immediate, Positive, and Personalized Feedback	Include mechanisms that provide immediate and positive feedback to reinforce correct behaviors and encourage continued learning.
4. Apply Psychological Approaches	Utilize techniques such as gentle prompting and reinforcement to promote sustainable behaviors among children.
5. Customization of Experience	Ensure that the tool allows for customization, connecting to children's everyday lives to strengthen empathy and emotional engagement.
6. Associate Practical Field Actions	Combine technology with practical field activities to consolidate knowledge and make it more relevant and applicable.
7. Use Social Robots or Artificial Intelligence	Consider integrating social robots or artificial intelligence technologies, such as using image recognition modules for waste detection and classification, to make the experience more interactive and educational.
8. Emphasize Intergenerational Interaction	Create opportunities for interaction between children and family members, using technology as a connecting point to amplify the effects of learning.

Final Considerations

The present research aimed to understand and gather insights into the latest trends in scientific literature related to the development of games and applications to teach and engage children on the topics of recycling and sustainability, from January 1, 2020, to May 10, 2024.

Several effective techniques were observed to capture the attention of young audiences, providing a more accessible and interactive learning experience on environmental protection principles. As media and technologies continue to advance, new alternatives and approaches emerge, and integrating the use of these technologies with practical learning initiatives proves to be an effective pathway for addressing sustainability and recycling.

Bibliographic references

BANDURA, A. **Social foundations of thought and action**. Englewood Cliffs, NJ: Prentice-Hall, 1986.

FINK, A. **Conducting research literature reviews: From the internet to paper**. 3rd ed. London: SAGE Publications, Inc, 2010.

KAVERI, G. **Household waste generation**: Understanding family practices and challenges in Singapore. Unpublished manuscript, 2021.

KIM, S., et al. Educational games and students' game engagement in elementary school classrooms. **Journal of Computers in Education**, v. 4, n. 4, p. 395-418, 2017.

KUROKAWA, H., et al. Improvement impact of nudges incorporated in environmental education on students' environmental knowledge, attitudes, and behaviors. **Journal of Environmental Management**, v. 325, 116612, 2023.

LANKES, M., et al. InterPlayces: Results of an intergenerational games study. In: **Serious Games: Third Joint International Conference, JCSG 2017**, Valencia, Spain, November 23-24, 2017, Proceedings 3. Springer International Publishing, 2017.

LOCREDITANI, M.; MERLINO, S.; ABBATE, M. Assessing the citizen science approach as tool to increase awareness on the marine litter problem. **Marine Pollution Bulletin**, v. 140, p. 320-329, 2019.

MOHER, D.; LIBERATI, A.; TETZLAFF, J.; ALTMAN, D. G.; The PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. **PLoS Medicine**, v. 6, n. 6, 2009. Disponível em: <<http://dx.doi.org/10.1371/journal.pmed1000097>>.

NINSIANA, W.; SEPTIYANA, L.; SUPRIHATIN, Y. Introducing eco-literacy to early childhood students through digital learning. **Journal of Education and Learning (EduLearn)**, v. 18, n. 1, p. 89-96, 2024.

PAREJO, J.-L., et al. Plastics as an educational resource for sustainable development: A case study in Ghana. **Sustainability**, v. 13, n. 12, 6727, 2021.

POJE, M., et al. Environmental Education on Sustainable Principles in Kindergartens—A Foundation or an Option? **Sustainability**, v. 16, n. 7, p. 2707, 2024.

PRAET, E., et al. Bottle with a message: The role of story writing as an engagement tool to explore children's perceptions of marine plastic litter. **Marine Pollution Bulletin**, v. 186, 114457, 2023.

PRAMLING SAMUELSSON, I. Why we should begin early with ESD: The role of early childhood education. **International Journal of Early Childhood**, v. 43, n. 2, p. 103-118, 2011.

ROSSANO, V.; DE CAROLIS, B.; MANZONI, P. Mini-games to Motivate and Engage Users in Learning Recycling Rules. In: **International Conference in Methodologies and Intelligent Systems for Technology Enhanced Learning**. Cham: Springer International Publishing, 2022.

SALAZAR, C., et al. From theory to action: Explaining the process of knowledge attitudes and practices regarding the use and disposal of plastic among school children. **Journal of Environmental Psychology**, v. 80, 101777, 2022.

SHEAVLY, S. B.; REGISTER, K. M. Marine debris & plastics: Environmental concerns, sources, impacts and solutions. **Journal of Polymers and the Environment**, v. 15, n. 4, p. 301-305, 2007.

TERÁN, Y.; GIMÉNEZ, A. Experiencias de educación ambiental en la catedra Biología del Programa Ingeniería Agroindustrial de la UCLA. **Agroindustria, Sociedad y Ambiente**, v. 1, n. 18, p. 132-138, 2022.