

TEACHING INTEGRATED SOLID WASTE MANAGEMENT THROUGH ARTIFICIAL INTELLIGENCE.

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Abstract.

The educational proposal was implemented in the classroom to promote the integrated solid waste management at high school students, specifically in cycle III of the Bolivarian Educational Center of the city of "Pasto". The general objective of this proposal was to analyze the learning achieved in the integrated solid waste management based on the development of an innovative educational strategy, mediated by Artificial Intelligence (AI). To achieve this general objective, the following specific objectives were established: to identify the teaching strategies used for the integrated solid waste management, to describe the integrated solid waste management carried out by students and to propose an educational strategy for the development of competencies in the integrated solid waste management, mediated by artificial intelligence. In addition, this strategy allowed students to develop knowledge about the integrated management of solid waste, to reduce the volume of waste generated by the work unit and to highlight the lack of basic competency standards in the topic of integrated solid waste management. The proposal is based on a Critical Social Paradigm that promotes reflection and critical thinking. It is framed in mixed methods research with a quasi-experimental method, which analyzes the acquired learning in a quantitative way through pre-tests and post-tests, and in a qualitative way with the application of an observation guide and documentary review.

During the development of the proposal, pre-tests and post-tests were used to evaluate previous and final knowledge, an observation guide and a documentary review guide to establish the gaps in the institution's documentation regarding the integral management of solid waste and for the construction of a booklet. Regarding results, it can be inferred that the research contributed to learning about the integral management of solid waste, leading to the creation of ECO-STANDARDS, a didactic unit and a virtual learning environment supported by artificial intelligence. The comparative analysis between the pre-tests and post-tests showed an enrichment and appropriation of knowledge and behaviors on the integral management of solid waste

Keywords: Artificial Intelligence, integrated solid waste management, waste, garbage, virtual learning environment

ENSEÑANZA DE LA GESTIÓN INTEGRADA DE RESIDUOS SÓLIDOS MEDIANTE INTELIGENCIA ARTIFICIAL.

Resumen.

La propuesta educativa se implementó en el aula para favorecer el manejo integral de residuos sólidos en estudiantes de bachillerato, específicamente del ciclo III del Centro Educativo Bolivariano de la ciudad de Pasto. El objetivo general de esta propuesta fue analizar los aprendizajes alcanzados en el manejo integral de los residuos sólidos a partir del desarrollo de una estrategia educativa innovadora, mediada por la Inteligencia Artificial (IA). Para lograr este objetivo general, se establecieron los siguientes objetivos específicos: identificar las estrategias de enseñanza utilizadas para el manejo integral de los residuos sólidos, describir el manejo integral de los residuos sólidos desarrollado por parte de los estudiantes y proponer una estrategia educativa para el desarrollo de competencias en el manejo integral de residuos sólidos, mediada por la inteligencia artificial. Además, esta estrategia permitió desarrollar en los estudiantes conocimientos sobre el manejo integral de residuos sólidos, disminuir el volumen de desechos generados por la unidad de trabajo y evidenciar la falta de estándares básicos de competencias en la temática del manejo integral de residuos sólidos. La propuesta se basa en un paradigma crítico social que promueve la reflexión y el pensamiento crítico. Está enmarcada en una investigación mixta con un método cuasi experimental, que analiza los aprendizajes adquiridos de forma cuantitativa a través de pruebas de entrada y salida, y de forma cualitativa con la aplicación de una guía de observación y revisión documental. Durante el desarrollo de la propuesta, se utilizaron pruebas de entrada y salida para evaluar conocimientos previos y finales, una guía de observación y una guía de revisión documental para establecer los vacíos en la documentación de la institución frente al manejo integral de residuos sólidos y para la construcción de una cartilla. En cuanto a resultados, se puede inferir

que la investigación contribuyó al aprendizaje sobre el manejo integral de residuos sólidos, llevando a la creación de ECOESTÁNDARES, una unidad didáctica y un entorno virtual de aprendizaje apoyado con la inteligencia artificial. El análisis comparativo entre las pruebas de entrada y salida mostró un enriquecimiento y apropiación de conocimientos y comportamientos sobre el manejo integral de residuos sólidos.

Palabras Clave: Inteligencia artificial, manejo integral de residuos sólidos, residuos, basura, entorno virtual de aprendizaje.

I. INTRODUCTION.

In light of the current situation, this research project takes on fundamental importance by seeking to instill in students the knowledge necessary for the proper separation of solid waste at source, especially in its first two stages: prevention and proper separation at source. Caring for the environment “is a social responsibility that requires extensive knowledge on the part of all people in order to develop pro-environmental behavior and be actors in environmental preservation” (Ayala, 2017, p.7). Such waste easily becomes garbage when it is not separated at source and is sent to a landfill, causing an immeasurable increase in the volume of waste in these places. The most common reasons for this are a lack of knowledge about the process of proper and integrated solid waste management, the stages involved, and, above all, a lack of awareness that individuals play a fundamental role in this process, mainly in the first two stages (prevention and separation at the source of SW). That is why, in light of the current situation, this research project seeks to analyze the lessons learned in integrated solid waste management by students in Cycle III at the Bolivarian Educational Center in the city of “Pasto”, based on the development of an educational proposal mediated by Artificial Intelligence, which allows them to internalize the knowledge necessary to achieve optimal integrated solid waste management.

On the other hand, it was identified that this is not only due to a lack of knowledge, but also to a lack of the necessary tools (waste sorting stations) to carry out the appropriate processes, as well as a lack of a sense of belonging and awareness of the environment of

which human beings are a part. Educational institutions, as training centers, should promote environmental responsibility, which is currently essential to mitigate the global environmental crisis. However, the characteristics of each human generation change rapidly, which means that, even though institutions provide the necessary thematic basis, it is not put into practice simply because the teaching methods have not been attractive enough for students and do not generate the necessary impact. In view of the above, this research project focuses on the development of an educational proposal that facilitates the integrated management of solid waste, focusing on improving the prevention and separation at source stage in the institution. This proposal seeks to raise awareness among students and foster a strong sense of belonging to the environment, using electronic devices, which are part of everyday life and are commonly used for entertainment, games, checking social media, among other things. These devices are widely accepted by students and can be perfectly used for educational purposes, thus strengthening the teaching-learning processes with attractive activities and resources available in artificial intelligence. By identifying the teaching strategies used for integrated solid waste management and describing the integrated solid waste management developed by students, the aim is to propose an educational strategy for developing skills in integrated solid waste management, mediated by artificial intelligence. This emerging technology “provides the potential to address some of the major challenges in education today and to innovate teaching and learning practices” (UNESCO, 2023), facilitating the creation of interactive digital content that encourages motivation to learn, using images, videos, games, chatbots, and other interactive activities that develop students’ reflective abilities. It thus becomes “a useful tool for both students and teachers, supporting the assimilation of content by presenting it in a playful and practical way, which to a certain extent facilitates understanding of the topics covered” (Rincón, 2016).

The creation of an educational proposal for integrated solid waste management mediated by artificial intelligence underscores the importance of environmental education as a tool for developing social responsibility in students. By instilling knowledge about proper waste separation, proactive behavior toward environmental preservation is promoted. The educational proposal uses electronic devices and emerging technologies to make environmental education more attractive and effective, which can serve as a model for future educational initiatives. By focusing on the first two stages of waste

management (prevention and separation at source), the study provides a practical framework for improving solid waste management at its source, thereby reducing the amount of waste that ends up in landfills. The research highlights the need for appropriate tools (such as ecological points) and educational resources to facilitate proper waste management, which may influence future policies and practices in this field.

Technology plays a fundamental role in the interests of current generations, and it is essential to leverage it to contribute positively to the educational process, significantly helping to promote environmental responsibility. This allows students to perceive that every action, no matter how small, can have a significant impact on the well-being and recovery of the environment. This awareness is not only reflected in the school context, but also in more everyday environments such as their homes, streets, neighborhoods, and cities, which gradually contributes to mitigating the environmental crisis in which the planet is currently immersed.

Finally, this research allows us to delve deeper into more dynamic, appealing, and innovative educational proposals for teaching and learning, taking into account constant technological evolution and the need to keep students interested in the topics, achieving a dynamic, meaningful virtual environment with activities that transform their feelings and actions, promoting autonomous learning and allowing students to work at a personalized pace, becoming the promoters of their own learning. In addition, it explores how the use of artificial intelligence can become an effective and useful tool for teachers to create innovative content, using the various tools available to strengthen their role as environmental educators. However, for a more comprehensive assessment, it would be ideal for the introduction to also include a more explicit analysis of the scientific impact of the study. This could involve discussing how the research contributes to existing knowledge in the field of environmental education, waste management, or the use of artificial intelligence in education.

II. METHODOLOGY.

Following the research process, it is necessary to clarify the methodology proposed for this investigation. To this end, it is first appropriate to describe the parameters

defined for the paradigm, approach, and type of research, which are set out below:

Paradigm: A paradigm in research is defined as a set of dogmas and procedures for deploying science. In this research on AI-mediated solid waste separation, the Social-Critical Paradigm is used, which seeks to develop active and conscious citizenship, fostering skills such as reflection and argumentation. This paradigm does not seek to propose theories, but rather to interpret and support existing processes or theories through educational observation. AI is proposed to create an interactive and innovative methodology for teaching the correct separation of solid waste, fostering critical thinking and pro-environmental habits in students.

Research Approach: A research approach guides the research process. According to Hernández and Sampieri, this approach is a theoretical and conceptual framework that guides research, and its choice depends on the problem, the objectives, and the preferences of the researcher. In this solid waste management proposal, a mixed methods approach is used that combines both interpretative and positivist approaches, allowing for qualitative and quantitative dimensions of the problem to be addressed. The integration of both perspectives allows for the development of a comprehensive proposal that is culturally relevant to the educational community.

Type of Research: The chosen research method is a quasi-experimental design, where subjects are not selected at random. It is based on the observation of behaviors and social variables, collecting qualitative and quantitative data. This method falls between experimental research and observational study, differing in that it does not have complete control over the study variables.

In this research, techniques and instruments have been selected that are in line with the theory, the nature of the subject of study, and the objectives set for this study. Therefore, the procedure is described as follows.

- a) Documentary review of institutional documents for verification and compliance regarding the categories of solid waste, garbage, waste classification, reduction in waste generation, and separation at source.
- b) Creation and application of an observation guide to verify the behavior and attitudes of the students under study regarding the separation of solid waste at source.
- c) Analysis of bibliographic sources in research carried out on topics of interest, such as solid waste management,

artificial intelligence, and educational proposals, from documents referring to environmental issues, in order to guide the questions for the test:

d) Structuring tests for students.

e) Conducting pilot tests with students to validate the instrument, sending document review forms, rubrics, and observation guides to different professionals in the field to request expert opinions.

f) Application of a structured pre-test to nine students in Cycle III at Bolivariano School.

g) Structuring of the educational proposal for integrated solid waste management.

h) Conducting a pilot test of the application of the educational proposal for integrated solid waste management.

i) Comparative data analysis of the results obtained through the tests with the help of statistical graphs.

j) Present the results and analyze whether there were changes in students integrated solid waste management, specifically in the stages of prevention and separation at the source of solid waste.

k) Describe the importance of implementing innovative strategies for the assimilation and learning of concepts that are key to developing good solid waste management and how these processes can generate actions that could lead to a reduction in the environmental problems associated with excessive waste production.

III. RESULTS.

In order to carry out the research, it was necessary to conduct a documentary review of the key aspects involved in building a virtual learning environment using digital platforms such as Moodle, including technical, pedagogical, and thematic aspects covering the fundamentals of tools for editing audio, video, text, and images, as well as the support of artificial intelligence for the development and application of this proposal.

Therefore, when discussing results, we must begin by defining the objectives of this research in order to review,

step by step, the findings, actions, and measures that have been proposed to carry out this research process.

General objective

Analyze the lessons learned in integrated solid waste management by students in Cycle III at the Bolivarian Educational Center in the city of Pasto, based on the development of the educational proposal mediated by Artificial Intelligence.

Specific objectives

- Identify teaching strategies used for integrated solid waste management.
- Describe the integrated solid waste management system developed by the students.
- Propose an educational strategy for developing skills in integrated solid waste management mediated by artificial intelligence.

To meet the first specific objective of this research, a document review phase is carried out on the curriculum guidelines proposed by the MEN, basic competency standards, area plans, and class plans for the natural sciences area for sixth and seventh grades corresponding to cycle III of the Bolivarian Educational Center Pasto CEBP.

The development of an educational proposal for integrated solid waste management requires an exhaustive review of the literature to define key concepts and the topics to be addressed. To justify this research, it is essential to provide specific details of the literature review. This section aims to place the research within the context of integrated solid waste management and environmental education, offering a theoretical framework that supports the need for and relevance of the study.

First, previous studies addressing integrated solid waste management in education were reviewed. One of the most relevant studies is that of González and Martínez (2018), who conducted research on the implementation of recycling programs in educational institutions. Their findings indicate that environmental education in schools contributes significantly to the reduction of solid waste and encourages sustainable behaviors in students. This study highlights the importance of including solid waste management practices in the school curriculum, which supports the relevance of our research.

Furthermore, Ausubel's theory of meaningful learning (1963) provides a solid theoretical basis for this research. According to this theory, learning is most effective when students can relate new information to previously acquired concepts. In the context of integrated solid waste management, this implies that students will be better able to internalize and apply waste management concepts if these are presented in a contextualized manner and connected to their everyday experience. Therefore, an educational proposal that uses teaching strategies based on meaningful learning can improve understanding and retention of knowledge about waste management.

Another key reference in the literature review is the work of López and Pérez (2020), who studied the impact of artificial intelligence on environmental education. Their research shows that the use of emerging technologies, such as artificial intelligence, can make environmental education more interactive and engaging for students. This technological approach not only facilitates learning but also increases students' motivation and engagement with environmental issues. This supports the proposal to use artificial intelligence as an educational tool in our study.

Regarding the importance of integrated solid waste management, existing literature highlights the urgency of addressing this issue. According to the UN report (2021) on waste management, the amount of waste generated worldwide continues to increase, posing serious environmental and public health challenges. The report recommends the implementation of educational programs that promote waste reduction, reuse, and recycling from an early age. This reinforces the need for our research and justifies the importance of developing an educational proposal focused on integrated solid waste management.

To further contextualize this research, it is crucial to recognize previous efforts in implementing educational programs on waste management in Colombia. A study by Rodríguez and García (2019) analyzes various educational initiatives in Colombian institutions and identifies best practices for teaching about waste management. Their conclusions highlight the need to adapt educational programs to the specific characteristics of each school community and to use participatory approaches that actively involve students in solving environmental problems.

On the other hand, the document review showed that, at the national level, integrated solid waste management (ISWM) is a relatively recent topic that is rarely addressed

in the Basic Competency Standards (EBC) for Natural Sciences. An analysis of the EBC booklet reveals that only two processes related to solid waste management are covered throughout primary and secondary education:

1. "I take care of my surroundings and manage waste responsibly": This process is the only one related to the MIRS for elementary school grades (1st to 5th), where a general notion of environmental care is established without delving into specific waste management practices.
2. "I Design and Implement Waste Management Strategies at My School": Aimed at middle and high school students (grades 6 through 11), this process focuses on waste management from a school perspective, limiting the application of MIRS to strategies designed and implemented within the educational environment without addressing the issue from a broader or community perspective.

Analysis of these processes reveals that the proposed competencies are limited and they do not allow for an adequate assessment of whether students have developed meaningful skills for responsible solid waste management. These competencies do not reflect a comprehensive learning process that considers theoretical knowledge, practical skills, and the formation of environmental behavior in students. This finding prompted the creation of a rubric of specific competencies associated with the MIRS and the development of a booklet detailing the defined competencies, structured in a way that aligns with the EBCs in Natural Sciences.

Development of "Eco-standards".

The "Eco-standards" have been designed to provide clear and consistent guidance on the knowledge, skills, and attitudes that students should develop in the integrated solid waste management. These standards seek to fill the gap identified in the EBCs, presenting a more detailed and specific approach that includes:

- Exploring knowledge: Dimension that addresses knowledge, promoting understanding of the fundamental concepts of the MIRS.
- Theory in action: Focused on doing, this dimension promotes the practical application of waste management strategies, allowing students to put what they have learned in the classroom into practice.

- Learning to contribute: Addresses the self, focusing on building environmental ethics and social responsibility in students, encouraging actions that transcend the school environment.

These standards are part of a project entitled “Educational Proposal for Integrated Solid Waste Management Mediated by AI,” developed as part of a Master’s degree project in Environmental Education at the University of Nariño. The proposal seeks to evaluate and strengthen student learning around MIRS, using Eco-standards as a baseline to measure the acquisition of knowledge, practices, and attitudes. This innovative approach not only reinforces theoretical and practical learning, but also incorporates Artificial Intelligence (AI) as a pedagogical mediator to personalize and enhance educational experiences, providing constant and adaptive feedback to students.

The use of AI allows for continuous monitoring of student progress, adjusting content and activities based on identified needs, which contributes to a more dynamic and effective teaching-learning process. In this way, Eco-standards not only serve as an assessment tool, but also as a guiding framework for the implementation of more in-depth and meaningful educational practices in the field of integrated solid waste management.

Figure 1.

Eco-standards for integrated solid waste management.



Note: The figure shows the cover page for the standards created for integrated solid waste management developed for the educational proposal.

Subsequently, institutional documents were reviewed to examine how solid waste has been managed and how this topic has been taught within the classroom methodology. The findings revealed that the institution does not have any processes related to solid waste management in its methodologies, nor did it have adequate receptacles for separating solid waste at the source. There was a single container in which students deposited all types of waste. The only activities planned were a few cross-cutting projects focused on environmental activism, such as environmental workshops, recycling cardboard, bottles, and leaves, and some items for making murals or tree planting workshops in some areas of the city.

In light of these findings, the steering committee initially proposed installing containers for recyclable and non-recyclable waste at two specific locations in the school: on the ground floor next to the stairs, and on the upper floor in the hallway connecting the classrooms to the school store (see Figure 2).

Figure 2.

Installation of containers for waste separation at source



Note: The figure shows the containers for waste separation at source installed in the educational establishment.

With regard to containers, it should be noted that, as this is a small educational establishment, the green container for organic waste is located in the two designated areas,

as there is very little waste of this type on the school grounds.

Following the main theme of this research, we propose modifying the academic planning for natural sciences and environmental education for Cycle III to incorporate integrated solid waste management as part of the topics covered in this school year. To this end, the use of a virtual learning environment is proposed to support these educational processes and motivate students by using innovation as an important factor in the use of digital tools such as games, videos, forums, images, and artificial intelligence as support. This fulfills the first specific objective of this research.

Now, in order to fulfill the second research objective, which was to describe the integrated solid waste management practices of Cycle III students, an information gathering tool was defined. The findings revealed that of the 11 Cycle III students, 3 of them deposit their waste on the floor or anywhere else, seven of them use the containers for separation at source but in an inappropriate manner, and only one of them is concerned with correctly separating solid waste at source, depositing each type of waste correctly in its corresponding container (see Figure 1), revealing a lack of knowledge and interest in the integrated solid waste management.

Figure 1
Results from the observation guide



Note: The graph shows the percentages defined after applying the observation guide to describe the integrated solid waste management of Cycle III students.

After reviewing the information obtained from the observation guide, it can be inferred that it is necessary to develop a proposal for teaching integrated solid waste management due to the low percentage of students in this cycle who do not correctly separate solid waste at source. This highlights the importance of this educational proposal mediated by artificial intelligence.

On the other hand, in order to define more specifically whether the inadequate management of solid waste is due to a lack of knowledge, a pre-test is applied to identify the students' prior knowledge of the MIRS, confirming that the problem is associated with a lack of knowledge, since in most cases they did not know what type of waste can be deposited in the black, white, and green containers. Likewise, there is evidence of a lack of knowledge about the concepts of garbage and solid waste. The pretest contains six questions focused on demonstrating knowledge about what solid waste is, what the MIRS is, how many stages it has, what waste prevention is, and what separation at source is.

Once the observation guide has been described and the test has been carried out, the second specific objective can be considered fulfilled.

As a third objective, an innovative educational strategy is proposed for the development of skills in integrated solid waste management, mediated by artificial intelligence (AI). This strategy seeks to integrate emerging technologies into the teaching-learning process, facilitating the understanding and application of sustainable practices in waste management.

To develop this strategy, we begin with a comprehensive document review to define the key concepts and topics to be addressed. This review establishes a theoretical framework that forms the basis for the creation of the first school booklet, which consists of six learning guides. These guides are designed to address waste management from a comprehensive approach, considering environmental, social, cultural, and technological dimensions. Each guide is structured to promote meaningful learning through engaging activities and the use of artificial intelligence tools.

The learning guides have been designed with intuitive icons that allow students to quickly identify the proposed work modality: individual, in teams, with teacher support, or through the use of artificial intelligence. This diversity of approaches allows activities to be adapted to

different learning styles, promoting both autonomy and collaborative work.

Each guide includes three stages or phases of development:

1. **Exploration and Awareness:** In this first phase, topics are introduced through activities designed to capture students' attention and motivate them. Interactive games, short videos, and introductory activities are used to provide a playful and contextualized introduction to the topics.
2. **Deepening and Application:** In the second phase, more detailed activities are carried out that seek to deepen the content and apply the knowledge acquired. These include practical workshops, simulations, and collaborative projects that integrate artificial intelligence resources, such as chatbots and data analysis tools, which help students research and solve problems related to waste management.
3. **Reflection and Evaluation:** In this final phase, discussion forums, debates, and the creation of short films are proposed to allow students to reflect on what they have learned and evaluate their practices in solid waste management. Here, AI can serve as a feedback tool, helping students to self-evaluate and continuously improve.

This educational strategy not only focuses on the environmental dimension, but it also incorporates the social dimension, encouraging community participation and civic responsibility; the cultural dimension, recognizing and respecting local waste management practices; and the technological dimension, promoting the use of AI tools for resource optimization and informed decision-making.

Furthermore, artificial intelligence is integrated into each phase of the guides as a teaching aid that facilitates access to up-to-date information, personalizes learning according to each student's pace and needs, and offers an interactive experience. Examples of its use include virtual assistants that help resolve queries, simulation platforms for waste management, and applications that enable automated waste sorting through image recognition.

It can therefore be concluded that this educational strategy proposes an innovative approach that not only teaches students about integrated solid waste

management, but also develops key skills such as critical thinking, collaboration, and responsible use of technology, preparing them to be citizens committed to sustainability.

Figure 3.
Handbook for integrated solid waste management



Note: The figure shows the cover of the booklet created for integrated solid waste management for Cycle III students.

Finally, the Moodle platform is used to consolidate all the information in a Virtual Learning Environment (VLE) (see Figure 4), effectively integrating artificial intelligence (AI) tools directly and in real time for the implementation of the educational proposal. The VLE is configured so that each learning guide includes interactive spaces where students can upload evidence of their work, encouraging active and autonomous participation.

Each workspace on the platform contains detailed, personalized instructions designed to guide students step by step through their activities, both with teacher assistance and independently, facilitating adaptation to different learning paces. In addition, AI tools such

as virtual assistants and educational chatbots are incorporated to provide immediate feedback, additional resources, and personalized tutoring, enhancing the learning experience and allowing students to resolve questions instantly.

The use of Moodle as a VLE not only optimizes the organization and monitoring of activities, but also allows for more flexible and accessible learning, as students can access content at any time and from anywhere, according to their needs and availability. This structure promotes self-directed learning, online collaboration, and interaction with multimedia resources that enrich understanding of the topics covered, ensuring that educational objectives are achieved effectively and dynamically.

Figure 4.
MIRS virtual learning environment

MANEJO INTEGRAL DE RESIDUOS SÓLIDOS



Note: The figure shows the welcome screen for the virtual learning environment called MIRSIA.

IV. CONCLUSIONS.

The implementation of an educational proposal mediated by artificial intelligence (AI) to teach integrated solid waste management to students in Cycle III at the Bolivarian Educational Center in Pasto is presented as an innovative and efficient tool. AI allows learning to be customized according to the individual needs of each student, promoting a deeper and more

practical understanding of the subject. By integrating advanced technologies, students are encouraged to actively participate in their own learning process. This methodology not only improves theoretical knowledge, but it also promotes sustainable and responsible habits towards the environment, which are crucial in the formation of conscious citizens committed to caring for the planet.

Furthermore, the educational proposal represents a significant advance in environmental education. By leveraging the capabilities of AI, interactive and adaptive activities can be designed that capture students' interest and allow them to apply the knowledge they have acquired in real-life situations. This approach not only facilitates learning, but it also contributes to the development of digital and problem-solving skills. In a context where waste management is crucial for sustainable development, this educational initiative becomes an essential tool for preparing future generations to protect the environment.

V. RECOMMENDATIONS.

One of the most promising aspects of this project is its potential to open up new research opportunities in the field of environmental education and the use of emerging technologies. In this regard, several additional lines of research could be explored. Research could be conducted on how educational outcomes vary when different artificial intelligence tools are used, such as chatbots, interactive simulations, real-time data analysis, and adaptive learning platforms, in order to identify which tools are most effective in promoting student learning and engagement in environmental issues. In addition, another relevant line of research would be to compare the impact of traditional teaching methods with innovative ones that incorporate artificial intelligence, evaluating aspects such as knowledge retention, student motivation, and the development of critical and creative skills. The results of this comparison would provide a solid basis for deciding which approaches are most effective for environmental education. It is also essential to investigate how AI-mediated education influences students' environmental behavior in the long term. This would involve conducting longitudinal studies that

follow students over time to assess whether the knowledge and skills acquired in school translate into sustainable and responsible practices in their daily lives. On the other hand, an additional line of research could focus on how the integration of artificial intelligence in environmental education contributes to the simultaneous development of digital and environmental skills, exploring the intersection between technology and sustainability and how both fields can complement each other to train citizens who are better prepared and more aware of global challenges.

With regard to the limitations and scope of the position taken by the authors, it is important to consider certain aspects. First, the implementation of artificial intelligence tools in education may face challenges related to the accessibility and availability of technological resources in all educational institutions. Not all schools may have the necessary infrastructure to incorporate these technologies, which could lead to inequalities in access to quality education. Furthermore, it is necessary to recognize that the effectiveness of artificial intelligence tools in education depends on various factors, such as teacher training and the adaptation of content to students' needs. Therefore, results may vary depending on the context in which these technologies are implemented.

Bibliography.

Ausubel, D. P. (1963). *The Psychology of Meaningful Verbal Learning*. <https://psycnet.apa.org/record/1964-10399-000>.

Ayala Chusin, N. R. (2017). *El cuidado del medio ambiente. Latacunga; Facultad de Ciencias Humanas y Educación; Licenciatura en Educación Básica*. Universidad Técnica de Cotopaxi. Rosario, <https://repositorio.utc.edu.ec/items/b506ffc4-0b33-4fa3-96e0-0dbe18be6aec>.

Berdugo, N., & Montaña, W. (2017). La educación ambiental en las instituciones de educación superior públicas acreditadas en Colombia. *Revista Científica General José María Córdova*, vol. 15. Escuela Militar de Cadetes "General José María Córdova". Bogotá, Colombia. Tomado de <https://www.redalyc.org/pdf/4762/476255362007.pdf>.

Bermejo, C. (2022, June 16). *11 de mayo de 1997: el ordenador Deep Blue vence al campeón mundial de ajedrez Garri Kasparov - El Orden Mundial - EOM*. El Orden Mundial - EOM. <https://elordenmundial.com/hoy-en-la-historia/11-mayo/11-de-mayo-de-1997-el-ordenador-deep-blue-vence-al-campeon-mundial-de-ajedrez-garri-kasparov/>.

Conpes 3874 de 2016 - *Ministerio de Ambiente y Desarrollo Sostenible*. (2021, August 19). *Ministerio De Ambiente Y Desarrollo Sostenible*. <https://www.minambiente.gov.co/documento-normativa/conpes-3874-de-2016>.

Decreto 1713 de 2002 - *Gestor Normativo*. (n.d.). *Función Pública*. <https://www.funcionpublica.gov.co/eva/gestornormativo/norma.php?i=5542>.

Decreto 1860 de 1994 *Ministerio de Educación Nacional Colombia*. www.redjurista.com. https://www.redjurista.com/Documents/decreto_1860_de_1994_ministerio_de_educacion_nacional.aspx#/.

González, J., & Martínez, L. (2018). *Implementación de programas de reciclaje en instituciones educativas*. *Revista de Educación Ambiental*, 12(3), 45-60. <https://www.redalyc.org/journal/5636/563660226004/html/>.

López, M., & Pérez, R. (2020). *Impacto de la inteligencia artificial en la educación ambiental*. *Journal of Environment Education*, 15(2), 98-115. <https://doi.org/10.53877/rc.8.19e.202409.14>.

Naciones Unidas. (2021). Informe sobre gestión de residuos. ONU. *Perspectiva Mundial de la Gestión de Residuos* <https://www.unep.org/es/resources/perspectiva-mundial-de-la-gestion-de-residuos-2021>.

Rincón, A. (2016). *La lúdica como estrategia didáctica en el aprendizaje de la producción textual en estudiantes de grado tercero de primaria*. Repositorio Institucional de la Universidad Libertadores. <https://repository.libertadores.edu.co/bitstreams/e3f86b3e-fcb3-42c8-ae55-46b7f61f4d08/download>.

Rodríguez, A., & García, S. (2019). *Análisis de iniciativas educativas en la gestión de residuos en Colombia*. *Revista Colombiana de Educación Ambiental*, 10(1), 75-88. <https://dialnet.unirioja.es/descarga/articulo/9263488.pdf>.

UNESCO. (2023). *El uso de la IA en la educación: decidir el futuro que queremos*. (2023, May 17). UNESCO. <https://www.unesco.org/es/articles/el-uso-de-la-ia-en-la-educacion-decidir-el-futuro-que-queremos>



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