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Article

Active Methodologies and Educational Technologies in International Contexts: An Overview of Practices in Environmental Sciences

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ABSTRACT
Active methodologies in the teaching of environmental sciences in the context of elementary school (early grades) are a topic of great importance in today's educational landscape, as they promote student agency and the meaningful construction of knowledge, expanding the possibilities for personalizing activities, analyzing learning processes, and creating more interactive and motivating experiences. In this regard, the present study aims to investigate how active methodologies, supported by technological advances, can enhance the teaching of natural sciences with a focus on environmental education in the early years of elementary school, identifying the main barriers and challenges to successful implementation and seeking to promote student engagement and contribute to critical and sustainable education. Through a qualitative literature review, the evidence regarding the use of active methodologies for teaching environmental science will be analyzed and synthesized. Studies published in the last 10 years will be examined, including scientific articles, book chapters, books, and teaching materials that discuss this approach on the Web of Science platform. Based on this compilation of information, a pedagogical proposal will be developed. Several active methodologies used in the teaching of natural sciences with a focus on environmental sciences in elementary school (early grades) were identified, highlighting the main pedagogical and technological challenges in integrating educational technologies into these methodologies. Thus, this study provided theoretical and practical insights for rethinking pedagogical practices, fostering greater engagement between teachers and students, and expanding the use of emerging technologies in the school setting.
Keywords: Active methodologies; Environmental sciences; Educational technologies

RESUMO
As Metodologias Ativas no Ensino de Ciências Ambientais no contexto do Ensino Fundamental (anos iniciais), constituem um tema de grande importância no cenário educacional atual, ao favorecerem o protagonismo do aluno e a construção significativa do conhecimento, ampliando as possibilidades de personalização das atividades, de análise dos processos de aprendizagem e de criação de experiências mais interativas e motivadoras. Nesse sentido, o presente estudo objetiva investigar como as metodologias ativas, apoiada pelos avanços tecnológicos, podem potencializar o ensino de Ciências da Natureza com foco em Educação Ambiental nos anos iniciais do Ensino Fundamental, identificando as principais barreiras e deafios para uma prática exitosa e buscando promover o engajamento dos alunos e contribuir para uma formação crítica e sustentável. Através de uma revisão da literatura com abordagem qualitativa será analisado e sintetizado as evidências sobre o uso das metodologias ativas para o ensino de ciências ambientais. Serão examinados estudos publicados nos últimos 10 anos, incluindo artigos científicos, capítulos de livros, livros e materiais didáticos que discutam essa abordagem na plataforma web of Science. Com base nessa coletânea de informações, será fundamentada a elaboração de uma proposta pedagógica. Foram identificadas algumas metodologias ativas utilizadas no ensino de Ciências da Natureza com foco em Ciências Ambientais no Ensino Fundamental (anos iniciais), levantando os principais desafios pedagógicos e tecnológicos na busca pela integração de tecnologias educacionais as metodologias. Dessa forma, este estudo forneceu subsídios teóricos e práticos para repensar práticas pedagógicas, favorecer maior engajamento entre professores e alunos e ampliar o uso de tecnologias emergentes no contexto escolar.
Palavras-chave: Metodologias ativas; Ciências ambientais; Tecnologias educacionais

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Introduction

Active teaching methodologies in natural science education—with a focus on environmental science in the context of elementary school (early grades)—are gaining prominence in today's educational landscape due to emerging technological advances and the climate challenges that have arisen worldwide. "It also aims to encourage the proposal and adoption of individual and collective alternatives, grounded in the application of scientific knowledge, that contribute to socio-environmental sustainability" (GOIÁS, 2019, p. 112). And to achieve better results in the teaching-learning process, it is beneficial to establish a partnership with educational technologies, including Artificial Intelligence (AI). "In the so-called 'globalized era' in which we live, technologies have been increasingly adopted as an integral part of educational systems" (Nogueira, 2025, p. 2) . Since sparking students' interest in reading and discussing concepts related to the environment and other topics is always a challenge—because children and young people today are more familiar with the use of technology—therefore, "in increasingly diverse educational environments, where students from different linguistic backgrounds share the same space, machine translation facilitates communication and understanding of instructional content" (PACHECO**,** 2024; p. 9). Consequently, it is necessary to adapt methodological approaches for addressing and discussing issues as important and timely as environmental problems.

Seeking a more reflective and critical perspective on the role of the teacher and the student in the teaching-learning process, Mendes (2025) emphasizes that the effectiveness of active methodologies depends on teacher mediation and the integration of theory and practice, which enables meaningful and contextualized learning. Thus, the integration of active methodologies with digital technologies represents not only a technological innovation but also a catalyst for student engagement and sustainable, conscious learning. By prioritizing active student participation in pedagogical practices in Environmental Sciences, the selected tools should emphasize critical thinking and a commitment to sustainability. As outlined in the curriculum documents that guide education in the state, "pedagogical practices should promote student agency, enabling them to construct knowledge and develop competencies and skills that make them active agents in transforming reality" (GOIÁS, 2019, p. 44).

However, we know this is not an easy process. "The development of active methodologies in the classroom remains a challenge and requires a paradigm shift" (ALENCAR, 2020; p. 21). Teachers must move beyond the role of sole transmitters of knowledge and adopt the role of mediators and listeners; students, in turn, must take a proactive stance toward knowledge construction. By actively engaging students in the process, active methodologies promote more lasting learning.

Based on this premise, the present study aims to conduct a narrative review of the literature to provide an overview of the integration of active methodologies in environmental education in elementary school (early grades). The study seeks to present theoretical frameworks and practical examples to enhance engagement between teachers and students and the use of active technologies in teaching.

Methodology

This is a literature review employing a qualitative approach to analyze and synthesize evidence regarding the integration of active methodologies in the teaching of natural sciences, with a focus on environmental sciences in elementary school. Studies published in the last 10 years were examined, including scientific articles, book chapters, books, and teaching materials that address the use of active methodologies in this context. This literature review sought to gather, evaluate, and discuss the available information on the topic.

The *Web of Science* platform was used for the literature search, and academic materials in English, Portuguese, and Spanish were considered using the following keywords: *Artificial Intelligence; Active Learning Methods; Environmental Science Education; Primary Education*, for the period 2015–2024.

The research, therefore, will be conducted in several stages. After selecting the references for bibliographic analysis, the research proceeds with the study and discussion of the collected data. The following inclusion criteria were adopted: Studies addressing active methodologies and artificial intelligence specifically related to the teaching of Environmental Science, and which describe pedagogical practices or analyses of their effectiveness and application. Exclusion criteria: Works outside the thematic scope, studies with insufficiently detailed methodology, or publications in languages not accessible to the researcher. Subsequently, the analyzed and selected articles were organized and presented according to authors, year of publication, study objective, scientific and pedagogical methods, main results, trends, and study limitations.

Thus, the proposed methodology will enable a systematic and critical analysis and study of the literature, ensuring the consistency of the procedures adopted and contributing to the development of a comprehensive view of the integration between active methodologies and artificial intelligence in Environmental Sciences.

Results and Discussion

During the application of the methodology, which consisted of a thorough literature review, it was observed that several documents initially identified were outside the scope of the study and were therefore excluded. The selected documents, in turn, were strongly aligned with the proposed theme and contributed significantly to enriching the discussion on the importance of active methodologies in the teaching of environmental sciences. This careful selection allowed for a more in-depth analysis and highlighted innovative pedagogical practices that foster student engagement and meaningful learning. The literature review covered studies conducted in different countries, enabling a comparative analysis of pedagogical approaches applied to the teaching of environmental sciences in elementary school. This international approach enriches the discussion by bringing in successful perspectives from diverse educational contexts.

Madureira and Batista (2024) highlight that the integration of Artificial Intelligence (AI) into the educational environment drives the development of more humanized and personalized practices by enabling teachers to monitor each student's individual progress. They also show that the use of AI optimizes self-reflection and self-regulation in learning, in addition to enhancing pedagogical tools and student motivation, highlighting the teacher's role as a mediator in the teaching-learning process.

From this perspective, it is essential to understand that the implementation of new technologies should not occur merely as a technical resource, but as part of a pedagogical plan that fosters student autonomy and agency. According to Dai et al. (2023), the collaborative development of curricula based on Artificial Intelligence can foster more participatory and contextualized teaching practices, in which educators and students learn together, exchange experiences, and reflect on the social and ethical implications of technology use. This approach broadens the possibilities for active methodologies to be integrated into the process of civic education, as it stimulates critical thinking, fosters creativity, and promotes students' social and environmental responsibility.

In this same vein, it is important to look beyond the use of technology and consider the holistic development of students, highlighting the importance of Environmental Education as a structural pillar of the school curriculum. Reinforcing the central idea that Environmental Education is fundamental to the development of educational curricula aimed at promoting sustainability—as shown in Table 1—it is evident that some countries have already demonstrated a commitment to including Environmental Education in their school curricula. These countries have faced challenges and devised strategies to ensure the effective implementation of this curriculum.

Table 1: Environmental Education and Sustainability in Different Countries

LIBYA	SPAIN and SWEDEN	UNITED KINGDOM	FRANCE
Inclusion in the curriculum starting in elementary school.	Small pedagogical decisions can transform the future. Planetary health	Environmental education with a focus on sustainable development.	Strategies: - Collaborative learning; - Critical reflection
Strategy: - Listening to teachers' needs; - Adapting content to the local context; - Make teaching more accessible and practical.	**Strategies:** - Active teaching methods; - Interdisciplinary.	**Challenges:** - Institutionalizing the proposal; - Lack of support for teachers.	**Challenges: - Institutionalization of the proposal;** - Continuing education for teachers.
	Teaching Practices: - Realistic and inspiring.	**Strategies:** - Support and pedagogical resources for educators; **- Training in sustainability-focused practices.**	**Outcome:** **- Experiential learning fosters autonomy and motivation**
Köprülü; Fayid; Kiraz, 2023	Baena-Morales; Fröberg, 2023	Chatzifotiou, 2018	Candelier et al., 2021

Source: Prepared by the authors (2025).

It has been observed that collaborative methods and *serious games* (SG) significantly increase students' knowledge of topics such as the SDGs and the 2030 Agenda. Thus, encouraging active learning methodologies helps strengthen skills and promote sustainable attitudes. (Saitua-Iribar; Corral-Lage; Peña-Miguel, 2020) . The "Make It Happen!" project, which is also aligned with SDGs 4 and 13 of the 2030 Agenda, demonstrated that project-based learning (PBL) combined with the Business Model Canvas (BMC) is highly effective, contributing to the development of more conscious, creative citizens who are prepared for the challenges of climate change and sustainability. (

The application of systems thinking in basic education, in a K-12 setting, shows that, although not highly structured, it promotes a better understanding of complex systems, engagement, and environmental awareness among students. (. For this reason, Environmental Education must be a continuous and multidimensional process aimed at developing the individual holistically, through effective and practical pedagogical approaches; With this in mind, (El Batri et al.. (2022) , discuss the "Scientific Awakening" program, which, in Morocco, has seen progress through improvements such as the provision of teaching materials and ongoing teacher training; much can be done to make Environmental Education more effective within the curriculum by developing useful knowledge and practical skills.

Thus, the active BSC *(Balanced Scorecard*) methodology can be an effective tool for planning, implementing, and monitoring environmental education programs at universities, facilitating a systemic and integrated view of educational initiatives capable of promoting greater coherence between environmental discourse and practices (De Andrade Guerra et al., 2018) . In the United Kingdom, another school program focused on K-12 education and conducted outdoors, called "Wild Citizens," is based on the principles of *inquiry-based learning* and the SSIBL (*Socio-Scientific Inquiry-Based Learning)*, encourages student engagement, enabling them to express complex ideas about environmental citizenship and potentially positively influence the society in which they live (Christodoulou; Grace, 2025) . This demonstrates how active methodologies can strengthen environmental education and responsible civic action.

In Botswana, the concept of *"wilding* pedagogy" is explored, which prioritizes direct contact with nature; that is, classes are held outside the classroom, seeking to foster more meaningful, ecological, and culturally relevant learning (Ketlhoilwe; Velempini, 2021) . In other countries, teaching methods focused on *outdoor education* are also being adopted*;* this approach involves experiential and collaborative learning but depends on effective changes to the educational structure and greater investment in teacher training, according to Jeronen; Palmberg; Yli-Panula (2016) .

In Spain, educational activities address the concept of sustainable mobility by using gamification as a strategy to promote cognitive and behavioral changes related to urban sustainability. (Sipone et al., 2019) In Finland, teaching methods have been identified that combine interactive learning and collaborative practices, emphasizing active student participation, the development of critical thinking, and the use of technologies and visual resources, all of which have proven effective in educating students who are aware of and engaged with sustainability (Yli-Panula; Jeronen; Lemmetty, 2019) . To promote scientific literacy and the development of critical thinking, the CREATE method (*Consider, Read, Elucidate hypotheses, Analyze data, Think of the next Experiment)* is a widely used tool in North American countries, fostering critical thinking and contributing to a more comprehensive view of science (Smith; Paradise, 2022) .

Table 2 shows different pedagogical approaches that seek to integrate science, technology, and sustainability, illustrating how innovative methodologies have been applied in various educational contexts. These practices, grounded in approaches such as STEM, STEAM, Roadmap, Gamification, and Immersive Virtual Reality, highlight the potential of active methodologies to foster creativity, critical thinking, and student engagement with contemporary socio-environmental issues.

Table 2: Innovative pedagogical approaches to sustainability.

STEM	**Integration of sustainability; 3D tools; applied creativity. (Voinohovska; Asenov, 2023)**
STEAM	Robotics; SDGs and climate change; creative solutions. (Ruiz Vicente; Zapatera Llinares; Montés Sánchez, 2020)
Service-Learning (STEM)	Partnerships; real-world environmental issues; transformative learning. (Vukojević Medvidović et al., 2024)
Roadmap	Interdisciplinarity; technology; critical thinking; sustainability skills. (Rodriguez-Andara et al., 2018).
GAMIFICATION (STEAM)	Minecraft; sustainable urban planning; child development and motivation. (Holik et al., 2024)
Immersive Virtual Reality (IVR)	Engagement and active learning; a complement to traditional teaching. (Laine; Korhonen; Hakkarainen, 2023)

Source: Prepared by the authors (2025).

Highlighting the importance of providing resources and encouraging students to address sustainable issues and discuss environmental challenges, tools such as gamification and the ClassCraft platform encourage students to reflect on sustainable topics, promoting environmental awareness and the adoption of more responsible and collaborative habits (Sipone et al., 2021) . Innovative, interactive, and student-centered methodologies can foster engagement and greater awareness in an education system that seeks sustainable development. The virtual game *Eco Art Explorer* can foster active environmental awareness among children (Bogdanic; Vuk, 2022) . The same is true in schools in the United Kingdom, where the use of *Life Cycle Thinking (LCT)* promotes environmental awareness through the analysis of the impacts of products and processes, and is even applied in educational board games (Kurisu et al., 2021) .

In general, the results show that the use of active methodologies, combined with technological resources and playful strategies, has fostered the development of a critical and participatory environmental awareness among students. The experiences analyzed show that when teaching connects with students' reality and lived experiences, learning becomes more meaningful and lasting. Thus, a promising and growing educational movement is emerging, in which different countries—including Brazil—are adopting practices that combine engagement, technology, and socio-environmental responsibility, reaffirming the essential role of education in shaping conscious citizens and agents of change.

In this regard, Araya-Castillo et al.(2022) emphasize that the teacher is an essential component of the educational process; it is through their emotions, experiences, and narratives that they inspire and motivate their students. They further highlight that the human and affective aspects of teaching exert a direct influence on learning by fostering meaningful connections and impacting the emotional dimension of education. This perspective reinforces the idea that true learning is a combination of innovative methodologies and the creative and sensitive abilities of educators who constantly seek to spark interest, bringing knowledge into the students' reality, and transforming the environment in which they are immersed.

In addition, the authors emphasize the idea that teaching practices involve fostering critical reflection and educators' ability to adapt to social changes and technological advances. (Araya-Castillo et al.2022) By recognizing the social context and promoting innovation, educators facilitate a more dynamic learning process that is connected to reality, intertwining motivation, knowledge development, and the individual's growth.

Conclusion

There is a growing need to incorporate current technologies into education due to the environmental, social, and technological transformations of the contemporary world. Thus, the integration of educational technologies into active methodologies not only transforms the way Environmental Sciences are taught but also prepares students to address the complex environmental problems of the 21st century with innovative solutions, fostering greater engagement and pedagogical innovation, as argued by Moran (2015) and Bacich and Moran (2018).

Based on the literature reviews conducted, it is evident that the integration of active methodologies and environmental education represents a promising path toward making the teaching-learning process more meaningful and transformative. As Paulo Freire reminds us, "there is a relationship between the joy necessary for educational activity and hope." The hope that teachers and students, together, can learn, teach, challenge ourselves, create, and resist the obstacles that challenge us"(FREIRE, 2006 , p. 43) . This perspective reinforces that teaching is also an act of hope and commitment to building a better world.

Practices observed in different contexts show that when students are placed at the center of the teaching-learning process, knowledge takes on meaning and connects to everyday life. The use of technologies, such as gamification, immersive virtual reality, and collaborative digital platforms, has proven to be an important ally in promoting engagement, creativity, and critical thinking. These experiences reinforce the idea that pedagogical innovation can go hand in hand with the development of ethical and sustainable values.

Highlighting the potential of active methodologies, Catapan and Souza(2019) show that their implementation in Brazilian education represents a significant step forward in transforming the teaching-learning process, fostering greater engagement, interaction, and meaning in educational experiences. Thus, environmental education, facilitated by active methodologies, is not limited to content but broadens students' ecological, social, and emotional awareness. By recognizing the essential role of educators in this process, it is reaffirmed that teaching about sustainability is also an act of hope—an opportunity to inspire generations to care for the present and build a more balanced and humane future. As Piaget argues, "the main objective of education is to create people capable of doing new things, not simply repeating what previous generations have already done." (PIAGET,1972 , p. 145) . This perspective reinforces the importance of critical thinking, an indispensable element in the development of conscientious and transformative citizens.

We realize, then, that the teaching of Environmental Sciences is crucial for the development of cognitive and socio-emotional skills in elementary school students (early grades), fostering more meaningful learning, supporting innovation in teaching practices, and offering viable pathways for constructivist teaching, using current technological tools to make teaching and learning more accessible and effective, and promoting a more critical and active environmental education.

This type of approach allows the classroom to become a space for experimentation and reflection, where learning is closely linked to action and transformation. Environmental education guided by innovative practices contributes to the development of individuals who are aware of their social and ecological roles and capable of interacting responsibly and creatively in the construction of a more sustainable society.

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